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UNITED STATES AIR FORCE

AIR FORCE LOGISTICS COMMAND

PROCEEDINGS
SANITARY &
INDUSTRIAL HYGIENE
ENGINEERING SYMPOSIUM

#1752

3-6 OCTOBER 1961

ENVIRONMENTAL HEALTH LABORATORY
McClellan Air Force Base
CALIFORNIA

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UNITED STATES AIR FORCE
AIR FORCE LOGISTICS COMMAND

SANITARY AND INDUSTRIAL HYGIENE ENGINEERING
S Y M P O S I U M

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OPENING REMARKS

Colonel Wm. N. Borah, M.C.
Director, Base Medical Services
McClellan AFB, California

I have the pleasure of welcoming you to the Air Force's first Sanitary and Industrial Hygiene Engineering Symposium. McClellan AFB is justly proud to host you for these next few days.

We have asked Colonel Cole to extend the official welcome of SMAMA to you participants in the Symposium. Colonel Cole was born in Edgewood, Illinois, in 1915. He attended the Illinois State Teachers College and taught school for three years in a one-room Illinois schoolhouse before entering the U.S. Military Academy at West Point in 1937.

Following graduation from the Academy in 1941, he entered flying training and received his wings on 7 March 1942. Colonel Cole is a Command Pilot with over 3,000 flying hours logged. He saw combat in Europe during World War II as a B-17 pilot.

He received his Master's Degree in Industrial Engineering from Stanford University in 1948; subsequently was assigned to Washington, D.C. as Chief of Procurement Policy Branch of the Interservice Munitions Board. This service group developed the Armed Forces Procurement Regulations and Single Service Purchase Fund, still in operation.

Colonel Cole was first assigned to SMAMA in August 1956, has held several directorate level positions until 8 September 1961, when he was assigned as SMAMA Deputy Commander. Colonel Cole's decorations include the Legion of Merit, the Bronze Star, the Air Medal with Oak Leaf Cluster.

WELCOME

Colonel Clifford E. Cole, USAF
Deputy Commander
McClellan Air Force Base, Calif.

General Landry, our Commander, is unable to be here today, but in his behalf I want to welcome each of you to McClellan.

We're proud of our installation here. We have a mission to perform that we consider vital to the Air Force. It may be interesting to note that we support about 35% of the aircraft that are flown in the free world today. This includes aircraft of our own forces and those we support for MAP countries generally, overseas.

We have at this base one of the two facilities that deal with the subject matter under general discussion today, and we are quite proud of that. In this mission of ours, we naturally have quite a large industrial complex, probably with more functions in it than you would find in a comparable installation in industry. The people here have the benefit of the Environmental Health Laboratory to help them in their work, and the facilities of this laboratory are also available to others in our assigned area of responsibility.

Since this is the first symposium of this kind, I think we should also feel very proud that you all here will accept what must become a pattern for your efforts.

By coincidence I learned the other night that industrial hygiene does pay off in terms of individual health. A gentleman in Sacramento told me that he used to work at McClellan during the war. He was one of a number of people working in Maintenance, who were having some kind of sinus difficulties. After considerable exploration, it was determined that there were fumes from some of the operations in Maintenance and that the people were breathing these fumes because they had no respiratory protective equipment, and this was the cause of the problem. By calling in the people who know how to handle these matters, they determined the exact cause of the difficulty, provided the necessary ventilation and individual protection. This same thing is going on all the time, and naturally contributes in no small way to the effectiveness of our people in those areas where there are industrial hazards.

Once again, Gentlemen, we are very happy to have you here at McClellan. All our facilities are available to you, and I hope you are comfortable in your quarters, wherever you may be. If there is anything that we can do to assist you while you are here, we stand ready to do so.

Welcome to McClellan.

RESPONSE AND AIMS OF THE SYMPOSIUM

Major General L. Ronder Braswell, USAF, MC
Command Surgeon, Hq AFIC
Wright-Patterson AFB, Ohio

As Command Surgeon for the Air Force Logistics Command, I certainly welcome you here to this first Industrial Hygiene Engineering Symposium. I want to thank you, Colonel Cole, and General Landry and Colonel Borah and all the rest of you for making the arrangements. Accommodations are very pleasant, suitable, and most enjoyable.

I have had a chance to go through the Environmental Health Laboratory and I want to compliment Captain Powell and his staff for the excellent job they have done in effecting the move and organization of the laboratory from its former building, and for the initiative shown in making the space habitable with a very limited budget.

We in the Air Force are highly honored that these outstanding men in our profession have taken time out of their busy schedule to help guide us in our mission here, and I'd like to take cognizance of Dr. Princi of the Kettering Laboratory, Dr. Ashe of Ohio State University, Dr. Quigley of National Lead, Dr. George Milly, the Scientific Director of the Army Chemical Corps Research Group and, of course, no symposium like this would be complete without Professor Hatch from the University of Pittsburgh.

As to the aims of the symposium, it is our major intent to afford an opportunity for the younger engineers and health physicists actually to meet these highly qualified men -- not only to just see them, but to meet them personally and be able to talk with them. Of course, there are many other highly qualified men of note in this profession whom I can mention, such as Colonel Grant from the Surgeon General's Office, Colonel Boysen from my staff, and others -- but after all, you came here to listen to the pearls of wisdom from these educators, not to listen to me, so I will not prolong this.

The next thing of paramount importance is getting inter-communication between industrial hygiene engineers. We are spread so thin that some of you don't get to know what the other people are doing, and at this symposium you'll be able to be here and chat with your colleagues and discuss how things are going at the various

installations; what's this or that -- how they have done so-and-so. These things are important; to see men of national prominence in their fields and get to talk with each other, and finally to put forth your problems. And don't be appalled if this man is a colonel or a major and you're a lieutenant. Dr. Princi and Dr. Ashe, Professor Hatch, Dr. Quigley, Dr. Milly, and all, are willing to talk with you and they are just as human as you and I, so don't hesitate to ask them questions.

Again, Colonel Cole, thank you very much, and we'd appreciate it if you would convey our sincere gratitude to General Landry.

THE USAF AEROSPACE MEDICINE PROGRAM

Brig Gen A. L. Jennings, MC
Office of the Surgeon General
Washington, D. C.

Environmental Medicine is ever assuming greater importance to the Military services and particularly to the Air Force which is the world's largest aircraft and missile organization. The Industrial Hygiene Engineer is a vital partner to the Aerospace Physician in this business of keeping our Air Force personnel healthfully productive. It is important that you specialists in the evaluation and control of man's working environment meet and discuss problems of common interest and new advances in your field.

Changes have been needed to meet the newer challenges of missile and space technology. This morning I would like to briefly apprise you of the aerospace medicine organization within my Directorate of Professional Services in the Surgeon General's Office. Later in the program Colonel Grant will discuss more particularly the Preventive and Occupational Medicine portion of our program.

Early last year the Aerospace Medicine Division was formed from administratively separate activities within the Directorate of Professional Services; namely, the Aviation Medicine Division, the Nuclear Medicine Division, the Preventive Medicine Division and the Office of the Medical Research Advisor. The reorganization was essential to the success of the Aerospace Medicine Program. Improved coordination and guidance were provided for the accomplishment of those medical efforts directly supporting human effectiveness so essential to the accomplishment of the Air Force mission. Colonel Karl Houghton directs the division with Colonel Bill Maret as his deputy. The division is composed of two branches, and each branch a number of sections. The Preventive and Occupational Medicine Branch consists of the Occupational Medicine, Public Health, Engineering and Bionucleonics Sections. The Flight Medicine and Research Requirements Branch is made up of the Aerospace Crew Effectiveness, Aviation Physiology, Research Requirements Sections and the Office of the Medical Research Advisor.

It is the mission of the Preventive and Occupational Medicine Branch to insure adequate training and effective use of physicians in Preventive Medicine, Occupational Medicine and Special Weapons Defense, and Sanitary and Industrial Hygiene Engineers, Entomologists and Preventive Medicine Technicians. These persons give the Air Force the Medical capability to anticipate and control environmental health problems and also provide for medical defense against CBR weapons.

The branch is the office of primary interest for 78 regulations, pamphlets or manuals. With the assistance of knowledgeable medical service personnel throughout the Air Force, these directives are constantly revised to maintain their currency. A notable regulation just published is one dealing with medical support of aerospace systems. In recognition of the importance of adequate medical input into the development of aerospace systems, this regulation delineates responsibilities within the medical service for input into planning documents required by the AFR 375 series regulations. Cooperation with the medical departments of the Air Force contractors, as well as between medical activities within the Air Force, has been emphasized. Medical problems frequently handled by non-medical people by default in the past will receive appropriate consideration by medical experts. Staffing adjustments have been made to provide capability to meet responsibility.

Lastly, personnel of the Preventive and Occupational Medicine Branch represent the Surgeon General as a member of Department of Defense and national boards and committees allowing an exchange of ideas and at times expert assistance on Air Force medical problems. The caliber of professional persons in such organizations as the Armed Forces Epidemiological Board and the National Research Council is outstanding.

It is the mission of the Flight Medicine and Research Requirements Branch to monitor aerospace crew effectiveness program and career management and utilization of flight surgeons. The branch also evaluates the effect of new and proposed weapons and space systems on aerospace medicine practice as well as participates in the planning and operational aspects of the National Space Program. B-70, X-15, Mercury, Dyna Soar and Apollo are examples of such systems. A research document library was established by the branch to support the monitorships of biomedical research by the technical consultants within the Directorate of Professional Services. The research documents are processed for storage by means of automatic data processing equipment which allows rapid retrieval of the valuable data contained in these documents. Another important activity of the branch concerns monitoring the physiological training and personal equipment support for all flying personnel.

Of all the responsibilities of the Surgeon General's Office, none is greater than promoting the development of highly cooperative, well motivated and effective medical service personnel. The training value of a symposium such as this, with its excellent agenda and authoritative speakers, is enormous. The opportunity afforded to discuss mutual problems with friends and experts is both enjoyable and stimulating. These symposiums will be a factor in influencing younger engineer officers in their decision to make a career in the Air Force. General Braswell, you and your staff are to be commended for your efforts in initiating the symposium.

PHYSICIANS IN OCCUPATIONAL HEALTH

Dr. Frank Princi
Kettering Laboratory, University of Cincinnati

I'm here this morning to tell you some of the things that we don't know, and you'll have more definitive explanation of the things that we do know as time goes on during the week. I do regret that it will be impossible for me to be here for the remainder of these sessions; however, I am very happy to be able to be with you at this time. I should like to discuss for you the entire field of industrial health from a rather broad point of view, defining it as I understand it.

Because of this last phrase, you will be aware of the fact that many of us probably understand it in many different ways. It would be extremely nice if I could feel that my way is the best. It is no basic insecurity that makes me feel otherwise, because I think I have sufficient self-confidence to assert any of my own ideas without reservation, but I make this statement because the entire field of industrial health is in a dynamic state. It is a rapidly developing field. It is relatively new, not only to you, but to all of us. Some of us here have had a small part in the development of this field. Some of us have worked on the fringes. Some of us have developed one concept and some another. The basic concept has been the same. We are trying to prevent death and disease by the products of man's great effort to industrialize his social community.

Many years ago an old philosopher said that man's existence was limited by the accumulation of his own excreta, and this is what we are trying to prevent. How we choose to do this makes an interesting study. I said that this is a rapidly developing and new field, and it is because prior to 1915 in the United States there was no such thing as industrial health, and I say this with all due respect and regard to those early men who did see in their patients some unfortunate consequences of exposure to industrial wastes or products. But there was no real concept. This developed rather late in this country, and it would be gratifying to me, as a physician, to be able to say that the medical profession in the United States, seeing the general population become ill because of exposure to a number of noxious materials, took themselves in hand and decided not only to study the problems, but to eliminate them. Such, however, was not the case. The impetus to industrial health and to industrial hygiene controls in the United States was given by the Industrial Hygiene Engineers. Perhaps at that time they did not call themselves industrial hygiene engineers, but none the less, this is what they were. Again there can be very little equivocation on this point. They saw the problems, and they tried to eliminate them.

You men are in pretty much the same situation. You are seeing the problems, and you are trying to eliminate them. It is interesting that in contra-distinction to the great achievements of the sanitary engineers, the industrial hygiene engineers could only limit the effects of the environment and not control it entirely. And this has developed into a somewhat different concept of environmental control. It is possible for the sanitary engineer to eliminate typhoid fever in the United States. In fact, he has done this, so a person who lives in this country and doesn't move out of it need not be inoculated against typhoid fever. It was possible, and continues to be possible, for the engineer to eliminate malaria and a number of other diseases which are caused by disease vectors.

This is not true in the entire field of industrial health. There is probably no industrial illness that has been eliminated entirely. The environment has been controlled, the effects of the various substances have been attenuated, but elimination has never occurred until a material was discarded completely or until something was substituted for it.

This brings me to the basic concepts of what we are talking about when we talk about industrial health, industrial medicine or industrial hygiene. I didn't mean to disparage the physicians when I said that this field was discovered by industrial hygienists, because fundamentally we must agree that all health problems are medical problems and, without the physicians to study the various persons who are exposed and to understand their physiological reactions, we don't know whether this material produces illness in an exposed population. We must, therefore, have a continuity of efforts and a cooperative attitude between both the discoverer of the disease and that person whose purpose it is either to control it or to eliminate it.

Now I shall use the term industrial hygiene rather broadly this morning to include those who are skilled in a knowledge of the environment and its control in all its phases to include both radioactivity and chemical analysis. You will forgive me for broadening the field to this extent, but I feel that I must for purposes of time. The field of medicine is a little simpler to define. The objective of the doctor is to discover the disease, find its incidence, and attempt to control it, manage it, or treat it. Doctors are peculiarly adapted to the discovery of disease, because during four years of medical school that is what they are taught - disease and its diagnosis. Unfortunately, however, the word "health" is almost never mentioned, and this poses a serious problem, because in the field of industrial health we pretend to maintain health, yet we have been able to define neither health nor disease and as is my custom, I should like to make an attempt to define both for you this morning. You will understand that these are my own opinions, and they are developed only from my own experiences, and since we are victims of our own experiences, we become somewhat prejudiced in favor of our opinions. However, since there is no definition for health, and since there has been no definition for disease, particularly applicable to this field,

it seems to me that we should know the objective before we attempt to achieve it.

Health has been defined in a number of ways. It has been defined particularly as the absence of disease. Well, this is a fine definition because disease was never defined. Health has been defined as the absence of disease, good emotional orientation, good sociological orientation, and so on. This is pretty broad, really having no meaning at all. Well, I'll give you a simple definition of health - one that is over 2000 years old, and it was first stated by Socrates when he said, "Health exists when man is in harmony with his environment." In other words, there is no conflict between man and his environment. He is happy about it, and nobody is unhappy with him. This means, by the way, that he may have a headache, but if he is still happy, he has health. He may have one leg, but if he's happy, he has health.

Well then, having given you this simple minded concept of health, I'd like to give you a somewhat more complicated concept of disease, because in this day and age we cannot accept clinical signs and symptoms alone as disease. In fact, one of the greatest dangers in our own field is the very acceptance of certain clinical signs and symptoms. I have a book that I am reviewing with somewhat great difficulty, because I would like desperately to say something nice about it. It is entitled, "Silicosis and Pneumoconioses in Sweden." It is written by some very, very nice people, and they have described a series of several thousand X-rays and classified them, and the results of these X-rays represent to them the incidents of silicosis and the pneumoconiosis. There are no atmospheric studies; there is no indication that anybody was ever sick or that anybody ever had a complaint. If we accept such a definition of disease, don't you see the danger? Any clinical sign can then become disease, just as it hasn't been too long ago - five or ten years ago - if you had a blood cholesterol of 225, that wasn't so bad--nobody cared; anyway, you didn't know about it. But if you have it today, you're in real trouble, or Merrell's wouldn't make so much money with that MER-29. So we have to have a working definition, it seems to me - a simple definition, one that we can all understand and one that will be useful in determining whether our study of the individual in an environment is revealing to us the effects of absorption of noxious material.

The mere fact that the man says that he is sick or well does not constitute disease. The mere fact that he does not have a heart murmur does not constitute disease. In order to arrive at a definition, I found it necessary to become a little more primitive than usual. Go back and study the original organism, and what do we find? We find that all biological organisms are defensive mechanisms because they live in a hostile environment. I didn't invent this - there have been two great books written on this. One is, "The Mirage of Health" by Rene Dubos, and the other, "The Wisdom of the Body" by Walter P. Cannon. I think both books are well worth reading by any layman. The organism is

defensive, and completely defensive, regardless of its biological structure, regardless of whether it is an amoeba or a human. The reason we have skin is to protect us from the environment. The reason we have reactive blood vessels is to accommodate to heat and to cold. The reason we have detoxification mechanisms is not to protect us against carbon tetrachloride, but to protect us against the toxins produced by the very food we eat. The reason we wear clothing is to protect us from our environment. Some of our clothing we wear for good, solid physical reasons, and some of our clothing we wear for psychological reasons. So they say the man who wears a four-in-hand necktie is a nice, mild fellow, and the man that wears a bow-tie is an aggressive individual, and the man who smokes a pipe is hiding behind it.

Well, there may be more truth to this than we know. The point of the fact is that everything we do is a defense against what we consider biologically - not psychologically, but biologically - a hostile environment. In other words, the biological mechanism is a reactive mechanism. If it didn't react, nothing would happen, and when this mechanism is in harmony, we have a state of health, because it is a happy mechanism. The defenses are up and they are adequate.

Now again as I've said before, we are all victims of our own experiences, so we defend ourselves in different ways. It is only the very, very primitive now who takes a gun and shoots his enemies. We're much more civilized, as we don't have to do that. We don't even call anybody names anymore; we damn him with faint praise. As Alexander Pope says, "Teach others to sneer without appearing to sneer at one's self." I would like to suggest to you that health, therefore, is a state of equilibrium and that this equilibrium is assaulted at all times by a great number of stimuli, that there is response to every stimulant on the part of any physiological mechanism. This is a continuous process; it doesn't happen once in a while - it's happening all the time. There must be a level or an area where no permanent injury occurs and where harmony still exists. This is only a theory, but if it is true, then this is a state of dynamic equilibrium. This is variable, but variable within certain limits. This suggests to you, does it not, that health has a broad range and indeed it does, because I doubt that here this morning we are all in the same state of physiological equilibrium. The fact is, I am certain of it, but I will not go into details.

One other thing comes out of this, however; if equilibrium is lost and this develops, and this does not return to within the normal range, we have disease, and perhaps it is chronic disease. We may have tissue destruction; we may have an aberration of a physiological mechanism; we may have anything, but we have lost our equilibrium. Equally important, however, is the fact that we have a situation where the stimulus is too great and has overcome the response; or the reverse could occur where the response has become too great, and even in the absence of the stimulus, we can still have disease. And this happens. This happens not only with industrial diseases - this happens even in infectious diseases. The best

known example of this is, of course, tuberculosis where, having for all practical purposes eliminated the viable acid fast bacillus, we nonetheless have an overgrowth of fibrous tissue which destroys equilibrium that we are now calling health. If this is true then, and I choose to think that it is, this signifies that we must study not only the response of the organism to a stimulus, but the range of that response, and that within a certain range, health does indeed exist.

Now there are many ways in which we can do this, and there are many ways in which we cannot do this. One of the ways is to study and understand the organism and its physiological responses so we understand their significance. The second way we do this is to study the environment, the material in the environment, and understand its potentiality for producing a stimulus. The first is called medical control, and the second is called industrial hygiene control, and when both of these are effective, we have what we are pleased to call a safe environment.

There are times, however, when one will be completely effective even in the absence of help from the other. I think this is a very important thing to understand. Optimally, we would like to think that the engineer can contribute as much to the doctor as the doctor can contribute to the understanding of the effects of the environment. This is not always the case, because some of these materials pose problems that are extremely difficult to assess or even to measure. A primary example of good engineering control has been the tremendous reduction in silicosis in the United States. I didn't say elimination; I said reduction. I would like to go off on a tangent just for a moment to demonstrate another point, which brings up a very interesting fact in the study of disease. Most of the persons in the world with far advanced silicosis do not live in the United States. Most of the classical descriptions of silicosis were written twenty and thirty years ago, when it was indeed a great hazard. The current classical descriptions are being written in other countries, and yet there is a great danger that, as physicians, we might apply these descriptions to what we are seeing in this country where the exposure is far less.

A good example of medical control in the absence of industrial hygiene assistance is an odd one that you probably don't know about. But for thirty-five years tetraethyl lead has been manufactured with practically no complete understanding of how much tetraethyl lead that men breathe while they are working. Despite this fact, however, by the proper collection and examination of both medical and laboratory data, the physicians have been able to establish medical controls that have practically wiped out the incidence of tetraethyl lead intoxication in the United States, so that now it only occurs by accident. As a matter of fact, men working in tetraethyl plants who have worked there ten and fifteen years say they have never seen a case of tetraethyl lead intoxication. These are unusual instances, however. By and large, both these fields are inter-dependent, and in order that the greatest value

to occupational health may be developed, it is essential that the industrial hygiene engineer know something about the problems of the physician and vice versa. I do not mean to produce any more doctors who talk like engineers and engineers who talk like doctors, because we have enough of those. I would like to suggest that a clear understanding of the problems encountered by the other fellow and a reasonable understanding of the field in which the other man works, will produce the mutual cooperation that is essential, because there are some things that are so inter-dependent as to allow no separation.

To get back to lead as an example, we know, or we think we know that the signs and symptoms of lead intoxication are produced by the circulating lead ion in the blood. But we know that the exposure to lead compounds will produce different reactions, depending upon the chemistry of the compound, so that a lead miner who works with lead sulfide and does not absorb lead, does not have lead intoxication. A battery worker who works with lead oxide does indeed have lead intoxication, and it is manifested mostly by gastro-intestinal cramps, insomnia, constipation and a series of other symptoms which we know and recognize well. We rarely see peripheral neuritis any longer, although it does occur. We also know that the level of lead in the blood will very nearly parallel the course of the disease or signs and symptoms, and this is good, useful information to have. We know that if the lead analysis is not done properly, we'll get everything wrong. But taking organic lead compounds, we find a different complex of signs and symptoms. In the first place, the man almost never has abdominal cramps. He doesn't have peripheral neuritis, but this lead affects the central nervous system directly. He becomes hyper-excitable, hyper-irritable, and usually has convulsions. In fact, he may become maniacal, and frequently does. And what is more interesting, is the fact that the level of lead in the blood is of no help in making the diagnosis, but the level of lead in the urine will very closely parallel the progress of the signs and symptoms - the same element, different compounds, different illnesses, different control measures. This we know about. It certainly happens with other materials, but it isn't just the chemistry of the compound, but it is also the physical state of the compound.

Let me give you another example. Cadmium oxide is an easily defined material and easily defined compound. When it exists in the form of a fume, it produces a chemical pneumonitis, pulmonary edema, and usually death. Its action is so fast and culminating as to produce practically nothing else. Cadmium oxide, however, is not only a fume. Cadmium oxide exists when finely divided cadmium is dispersed in the air and becomes oxidized, and it becomes oxidized very readily. When it becomes absorbed, it results in the excretion of low, molecular weight proteins, lower nephron nephrosis, and sometimes a marked degree of emphysema, depending upon the size of the particulate matter, and it's still cadmium oxide. But cadmium oxide is also a red pigment - one of the best known and enduring of the red pigments. This is rapidly absorbed and rapidly

excreted and tremendous amounts of this material may be absorbed and excreted without any significant clinical signs or symptoms.

I hope I have been able to show you the inter-dependence of all the specialists who work in the field of industrial health. I'm trying to say this simply without any scientific terms such as parameter. and these days you can't write a paper without writing in the word parameter. I looked it up three times and couldn't understand the definition, so I gave it up. To make it somewhat scientific, you have to use the word.

I would like to spend just a moment on this question of team concept. We're great people for teams in the United States, and if I've heard the word team used, it's in the field of industrial health. Everybody says we work as a team; we do the work that has to be done as a team, or they work as a team. It gives me the great and glorious impression that a team is just a bunch of nice boys who get together and see that something has to be moved, and they all put their shoulders to it and they move with equal effort. That's a lot of nonsense! I was curious about a team one day, and I looked up the word "team" and found out the word "team" began way back in the early days of the Anglo Saxon Empire when the use of horses was first developed for carrying burdens. The man who invented the word tied it strictly to horses, and he studied this business, and this is more than what we do today. He found out there was an optimum number on a team. Too many were no good, and too few were no good. He found out, for example, that four horses were better than two, and six horses were better than four, but eight horses were not better than six, and twelve horses were completely unmanageable. So a team means specifically six horses. It also means something else. It means specialized horses. Most of you who are old and gray will remember the old dray horses. They had a team, a six-horse team, and the first two were called the lead horses, and they couldn't pull worth a damn, but they knew where to go. And the next two were called swing horses and they could pull, but they could also follow. And the last two were called wheel horses, because all they could do was pull; they didn't have any idea how to follow or lead. That means that in this team, and this is a highly successful team by the way, you need specialists, but you need direction; you need somebody whose shoulders may not be as broad or as great, but who knows where to go.

There are too many problems in this particular field of occupational health, or environmental health as we may call it, that are not really what they appear to be, and unless someone gives them direction, the whole team is lost, I'm afraid. I read a report the other day, and now you know from industrial health we go into environmental health and air pollution, if you'll pardon the expression. The report was by a group of great physicians and engineers, and I'm happy to give you the statement of this group, because it involves both physicians and engineers, men highly respected in a number of societies. Their conclusion, after studying the entire air pollution problem in the United States was,

"We don't know what pollutes the air; we don't know whether disease or illness occurs, but we must do something about it before it is too late."

Gentlemen, I don't know what they are talking about. In other words, let's solve the problem regardless of what the problem is! This is what we're going to do. I would like to suggest that we spend our time looking at the obvious and try to find out what we really see, and see if it is there, and not employ our prejudices in trying to arrive at solutions.

In conclusion, I would like to tell you a little story I tell my classes when I try to impress them with the idea of seeing the obvious. It goes like this: "If she calls you to her bedroom in the middle of the night, and through her half-closed eyelids you detect a telltale light, if her bosom heaves tumultuously like the wave upon the ocean, and her breath comes short and gaspingly, betraying her emotion, if she looks at you imploringly as you hold her trembling hand to alleviate her suffering the tortures of the damned -- that's asthma."

ENGINEERS IN OCCUPATIONAL HEALTH

Prof. Theodore F. Hatch
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University of Pittsburgh

I don't have any particular reason for telling this little story I read the other day. But I'm going to tell it anyway, as it may have some connection with what I'm going to say. It has to do with a very imaginative man on the staff of the New York Times who received a child's book for review. It occurred to him that the best person to review a child's book would be a child, so this book was sent to a nine year old boy for review. The child sent his review in with this concluding sentence: "This book on penguins contains a lot more information about the penguins than I am interested in."

My associate, Dr. Kammer, was talking at one of our seminars the other day on the subject of "Team." He said, with deep feeling, "If there is one word I detest, it's this word 'team' for the very reason that there's an implication that, somehow or other, great things will come from bringing together in one office a group of people representing various disciplines or professions which seem logically to have something to offer to the unfolding and the understanding of a problem "

I think we do, indeed, make a great deal of the point of the necessity for crossing disciplines and bringing various professions together in our field of Occupational Health. I think if we look back, particularly and most specifically in this country, we see that the idea of a "team" is something that emerged logically out of the unfolding of the problems with the kind of leaders that Dr. Princi was mentioning, and that after the work was all over somebody observed that they had a team. But the team had emerged logically, and I might go a little further than Dr. Princi did in emphasizing the matter of inter-relationship between the several disciplines and professions involved, to suggest that in the successful development of this approach we have almost come to the point where any one member of the group is no longer able to identify what he is doing in connection with the problems in the parent field from which he came. As I look back and read some of the other Public Health Service studies on the health of the workers in the dusty trades, I think that you can see that those doctors were thinking more about problems that were outside of what other doctors would call medicine. Similarly, the engineers, the geologists, the chemists and the statisticians, have lost their identities in terms of their basic professions and have become completely immersed in this central problem.

We have to have some word for it, and I suppose "team" is as good as any other, but I agree with Dr. Kammer that the need for the team and the nature of the team and how it develops must come from a concentrated effort in the studying of a problem. You don't get a doctor, a chemist, an engineer, and a statistician, etc., put them together and then automatically, as a consequence of that, have a team due to the fact that they are in the same office, sharing desks. I'd like also to expand on this a little bit for further emphasis of this point, and I think I'd like to express the saying a little differently, graphically speaking.

Dr. Princi said that no one has adequately defined health or disease, but I suspect that there is need for a definition of something between these two. For lack of a better term I have called it "impairment," a departure from health, a basic underlying disturbance of this balance that Dr. Princi was speaking of, to distinguish clearly between underlying and impairment and disability, or disease (Figure 2).

We all go by some route or other in the course of a lifetime and the path that we take depends on the kind of stresses that we encounter in our environment and our inherent capacities for dealing with these stresses. We may follow various pathways but in general I suggest that we follow a path that is pretty well characterized, the point being that we move down the scale in the course of living, a considerable fraction of the total distances with minimum movement up this scale, but beyond such a critical point in our life's history, further increments on this basic scale result in rapidly increasing increments of breakdown of the system on this scale.

In the area of health defined by Dr. Princi, Socrates, and more recently Dr. Kammer not only do we quite adequately deal with the stimuli of the environment, but I think we have to have these stimuli. To enjoy complete health, we've got to be subjected to such disturbances in order that our mechanism for dealing with them can be kept in good shape and we are provided with various compensatory mechanisms which enable us to deal with further impairment along this line.

Outside of this normal period of adjustment, by drawing on these compensatory mechanisms, we can limit the consequences in terms of the overall physiological welfare, despite the advancement along this scale of impairment. I suggest further that on the relationships that Dr. Princi spoke of, we have very successfully built our whole field of Occupational Health (Figure 1). That is to say, we have demonstrated relationships between one kind and another, in one degree of magnitude or another, of environmental

and the response in man, and that these relationships have been established by relating events to environmental stress. Some of the earliest relationships between stress and response in man were measured, as far as the response was concerned, by counting the number of dead people, or dead animals in the laboratory. We've moved largely away from that, but if you look at the epidemiological evidence in literature, there's a relationship between the defineable medical status of disease and the underlying stress factor. Now, in terms of acute disturbances on which we have built most of our security, it's evidently all right, since we've made practical use of these relationships. But I suggest that even these relationships were not truly fundamental because the time relationship between exposure and terminal response was so short. I suggest that what is happening is a consequence of the successful controls that have been applied. Take silicosis as an example. Without being full aware of it, we have pretty largely run out of the nourishment which can come from a study of this area. As an engineer, this disturbs me a great deal. While we, as engineers, would recognize that the doctors don't always know what they are talking about, they nonetheless have a certain favorable position that we don't enjoy. They presume to know something about man. The engineer, the chemist, the physical scientist, obviously out of past experience and education has no reason whatsoever to have any independent ideas about man, even though he is one himself. This disturbs me because as physical scientists or engineers we have no place in this field of Occupational Health, unless we can demonstrate to ourselves and to our own professional colleagues and to the others in this "team" that we, by virtue of certain capacities for identifying and measuring factors in the environment, can thereby make useful predictions as to what's going to happen to a man.

This is a little lecture I give my students every year. I know of no physical measurement that can ever be made in the environment that automatically tells you what will happen to a man in that environment. Now, having said that to non-medical people, I then turn to my medical students and point out to them that there is no diagnostic technique that will automatically tell them that, because they find a certain disturbance, it was caused by something in the environment. Even a very specific, diagnostic finding would not tell you this until somebody had first done some research and said it was, in effect, related to something in the environment. So it works both ways.

At any rate, as far as I am concerned, all our efforts for security and all medical proof of security, rests upon the reality of highly specific relationship between stress and strain; stress as identified and measured in the environment, and strain as identified and measured in terms of response. And we have enjoyed that security out of the correlations that have come from measuring response in this matter. I am suggesting as a scientist

that some of those relationships were not as real as the high correlation coefficient would suggest, but that the real relationship is between the stress of the environment and an alteration on this scale rather than on this one.

I think that a beautiful illustration of this would be the right heart failure of a coal miner. Breathing coal dust didn't do any harm to his heart; on the contrary, the reason he died of a right heart failure is because he had a good heart. The terminal fate was something brought about in consequence of his being a coal miner, but there was no one-for-one correlation between the exposure to the dust and what happened to his heart. I presume another man could go in another direction and could fail in some other basic part of his total physiological structure. So I believe as we progress in our accomplishments, reducing more and more the obvious relationships, we inevitably are confronted with a necessity for some of the adequate measurements along this scale; secondly, developing some appropriate basis for interpreting such fine points; but more particularly finding ways to measure along this scale for purposes of correlating with measurements on the environment.

I'd like to go back into the typhoid fever days that Dr. Princi spoke of to recall another book which you ought to read some time. It is a book called "Typhoid Fever" written at the turn of the century by my old professor at the College, U. C. Whipple. In this book is what is known as the "watermelon diagram. It is one of the most remarkable diagrams that I can think of. Really, the whole book is portrayed in this simple diagram. Here is an individual with typhoid fever. Here is a susceptible individual somewhere within a time-space contact with this source of infection. To deal successfully with the problem of preventing the spread of the disease from the source to the potential victims, we must identify the causative agent, the typhoid bacillus; we must identify the way in which it gets out of this reservoir, through the feces, etc. We must identify the pathways through which this causative agent can travel and move from the source to the potential victims, and if we have a deep enough understanding of the nature of this causative agents, its magnitude, its means of moving out from its center, then we can construct significant barriers around the individual to prevent or minimize the likelihood of the force getting to the critical cycle within the potential victim. The history of typhoid fever in this country is a magnificent demonstration of the reality of all this.

The history of the successes we have enjoyed in the Occupational Health Field, although they have not been quite so complete as Dr. Princi suggested they have for typhoid fever, we have been able to identify and give significant, quantitative meaning to the etiology of occupational health and occupational disease.

It means nothing to say that carbon monoxide causes a particular form of physiological disturbance. It doesn't, as a matter of fact, under some circumstances. One of the largest users of lead in this country doesn't have, and never did have, any problems with lead intoxication because the circumstances under which this potentially toxic substance is employed are such that the chemical just doesn't get out into the environment.

The first epidemiological study in which I ever got involved had to do with typhoid fever back in the middle twenties when the problem was already sharply on the down scale and it became possible, therefore, to do some differential epidemiology. The study had to do with the following question: In a given total population within the state of Tennessee, what would be the relative risk of becoming a victim of typhoid fever if you lived in a community of a given size? Results of the study were very intriguing and indicated that if you wished not to get typhoid fever in Tennessee at that time, the best place to live was in one of the larger cities; the second best place to live would be completely out in the country; if you wanted to get typhoid fever, the place to live would be in a community of about 1500.

The significance is this: in the rural situation, distance was a significant factor and the opportunities for common avenues of contact were so relatively few that, despite the lack of any real sanitary control, there was very little likelihood that the organisms would move from place to place.

Now, as population concentration increases, distances shorten and a point is reached where there must be a common milk supply, a common water supply, etc. The opportunity for the establishment of avenues increases, but if the population is large enough it becomes strong enough as a social and economic unit to afford all the necessary protective measures. So the neglected population at the time of the study was the group that was too big to be rural and too small to be urban. Here again we have an illustration of how the sharpness of success depends upon the sharpness with which the etiology and etiologial relationship can be established.

I'd like to go back to "team" a moment to suggest further that we ought to keep sharply in mind something which is deeper than the notion of having a group of people working together. I suggest that it is absolutely essential to have these either by bringing many people together or finding them all in one person, because the doctor cannot fully understand his part of the problem without relating it and indeed modifying some of his medical thinking in the light of this man-environment situation. Similarly, on the environmental side, it is impossible to establish the most refined kind of physical

measurements necessary to get the right answer, unless there is a real understanding of the point that when we engage in making a very profound intellectual commitment -- that, somehow or other what we are going to get by using a series of physical instruments and measurement procedures is, in some proper way, a significant substitute for a man.

I remember going on a mission to the Atomic Energy Commission a few years ago and I think I visited every AEC installation in the country. In the course of my travels I went to one laboratory where I met a young man who showed me, with justifiable pride, what he had recently been doing in the way of refining an instrument. What he had done was an intellectually high level piece of work in physics and I am sure would make a very good paper for the American Physics Society. He was properly very proud of it and I certainly didn't have the heart to tell him that the reason I was there was that I was carrying on an inquiry as to whether this measurement should be made at all or not, regardless of how precisely it might be made. It did, in fact, reflect in some way - not a physical event, but a biological event, so I was stopped at this point.

Speaking particularly to those of us who come to this field from the physical sciences and engineering, our whole intellectual and professional security depends upon the reality of these relationships and upon the success with which we have devised physical procedures for assessing the environment, not for the purpose of finding out what there is in the environment, but for the purpose of making meaningful predictions as to what could happen to a man if he is there in place of the instrument.

In closing, may I again suggest this works the other way, also. The understanding on the man's side requires similar recognition of the environment. But I'm speaking particularly to my own group, and I would like to emphasize this point, especially - don't fall in love with your beautiful instruments. Indeed, they are getting prettier and prettier as the years go by, but no matter how pretty they are, they will never provide what we are after unless they have been calibrated biologically rather than physically.

REVIEW OF NITROGEN TETROXIDE EXPOSURE IN A MISSILE INDUSTRY

P. J. Clancy, M. D., S. L. Watson, M. D., John B. Reardan, M. D.

Speaker:

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Many authors have speculated about the appearance of lung disease caused by oxides of nitrogen which does not contain nitric oxide. Our search for an instantly ready, extremely powerful, fuel system for liquid propelled missiles has provided an opportunity to study lung disease caused by oxides of nitrogen deficient in nitric oxide.

We manufacture and test the Titan Intercontinental Ballistic Missile's power plants. The oxidizer used in these engines is Nitrogen Tetroxide. It is a heavy red-brown liquid which consists of nitrogen dioxide and dinitrogen tetroxide with less than 0.1% water present. Since 1959 we have fired over 30 million pounds of this material. Fifteen million pounds of other storable oxidizers and fuels have been used since 1951. We have had three gas emergencies occur which were connected with the handling of Nitrogen Tetroxide. There have been possible exposures to twenty-two people in these three emergencies. Two cases of lower respiratory tract disease developed. There have been no fatalities, and disability has been temporary in nature.

Our operations are conducted out of doors, or in buildings not designed to protect people from the elements. Therefore, the wind is blowing in one direction or another almost all of the time. Our only scheduling parameter for storable testing is the availability of hardware. The number of employees, in a given area at the time of an upwind test using Nitrogen Tetroxide, is determined by the number of high capacity ammonia absorbing cannister masks and Scott Air Packs available in the area. Gas emergency drills are unscheduled and occur at least once a week in all areas. They are carefully monitored by the Test Area Safety Engineer and supervisors. These procedures are too detailed to be explained at this time, but are available on request. They were developed as a direct result of a gas emergency which occurred on the night of January 20, 1960.

Description of the Incident:

Sixteen people were working down-wind a valve test operation, when a five inch line broke and spilled about two hundred gallons of Nitrogen Tetroxide onto the floor. The evolving gas was carried by a fifteen mile an hour wind to an adjacent work area and exposed these men from one to two minutes. The man most seriously ill was a thirty-four old Instrumentation Technician who was working below ground level at the time of the exposure. He thought a power failure had occurred as the lights went out; then he smelled a strange odor, thought it was in the valves he was working on and climbed out of the hole to see that

the lights were still on but were obscured by a brown cloud. At this point he began to cough and continued to do so for many weeks thereafter. The other men in the area were leaving, and he ran to the control room (about 250 feet) where he had to sit down. Two other men caught him under the arms and helped him to the area Guard shack (another 500 feet). There he was placed in a station wagon at which point he lost consciousness.

Clinical Course:

It is not more than a ninety second trip to the Aid Station. On arrival, there the man was apneic and cyanotic. He was placed on oxygen and given artificial respiration. As soon as it was discontinued, he would turn blue. By this time the nurse had several others with paroxysms of coughing standing in the station. She broke an ammonia ampule and put it under the oxygen mask. This stimulated respiration long enough for her to get the others on oxygen.

Within forty minutes of the exposure vital signs stabilized, and he was taken out for a chest X-ray, physical examination, and lab work. The X-ray and lab work were negative. At the aid station his pulse had been 102 and thready with a blood pressure of 90/60. Respirations were questionable. The doctor's examination fifty-five minutes later showed a blood pressure of 108/74. The patient was extremely agitated, hyper-ventilated, coughed intermittently, and had shaking chills. He was conscious, alert, and cooperative. After the examination, he was comfortable, relaxed, in good spirits, and seemingly in no distress. Two hours after the exposure he was complaining of chest pain, extreme dizziness, and had a dry hacking cough. Five hours after the incident he was hospitalized. Chest X-ray at that time was negative. He was hyper-ventilating, had an intermittent hacking cough, and was complaining of numbness of the arms and legs and a slight discomfort across the chest. His pulse was 75; blood pressure 120/75. Respirations were irregular at 24.

Chest X-ray some nineteen hours after the exposure showed a diffuse, disseminated, and generalized nodular density throughout the lung parenchyma. The second day following exposure there had been some extension of the process. However on the third day after the exposure his symptoms were somewhat improved. He was afebrile and anxious to go home. Vital signs had returned to his previous normals, and he was discharged. Hospital laboratory work on the first day following the exposure was within normal limits except for some polymorphonuclear leucocytes in the urine. Two days after the exposure the white count had risen to thirteen thousand with a normal differential. The sedimentation rate remained at 4 millimeters an hour throughout his hospital stay. The patient was seen approximately every other day following discharge from the hospital and continued to improve.

He returned to work eight days after the exposure and did light work. However, deep inspirations triggered paroxysms of coughing, and he had exertional dyspnea. X-rays were taken throughout this period and were interpreted as normal. Due to the psychological make-up of the individual, not too much emphasis was placed on his complaints, although he was observed frequently.

Follow-Up:

One month after the exposure the patient complained of a twenty-four pound weight loss, some shortness of breath, and chest pain with occasional raising of blood-tinged sputum. His temperature was 99.8. Physical examination was not remarkable. He was sent home to bed on steam inhalations and temperatures twice a day. His temperature fluctuated from normal to 103 during the following six days, but whenever he was examined by a physician his temperature was in the normal range, and he was asymptomatic. Chest X-ray on the 23 of February showed a questionable fine density in the parenchyma. After three more days of normal physical examinations with abnormal temperatures and symptoms in the evenings, the patient was rehospitalized. He was in acute distress. Moving about on the bed caused severe paroxysms of coughing. His temperature was 99.4, pulse rate 110, respirations 40/min, blood pressure was normal. The lungs were hyperresonant with marked irregularity in breath sounds, inconstant wheezes, rales and rhonchi. Urinalysis showed a trace of acetone. Sedimentation rate was 41 millimeters per hour, cold agglutinins were negative. White count was 16,000, 74% of which were polys. The chest X-ray showed definite fine nodular densities.

He was somewhat calmer in the hospital, but his symptoms persisted, and on March 1, 40 days after the exposure, he was given 80 units of ACTH intravenously and put on dexamethasone 2.5 mgm. t.i.d. with an ulcer diet. His symptoms changed markedly. Breathing was much better although rales did persist. Forty-eight hours after therapy was started, the X-ray improved, in that there was a slight but definite decrease in the size of the nodules.

He was discharged on the 13th of March on a reduced dosage of Dexamethasone. By April 4, he was deemed able to perform light work, but the Test Area did not feel that it was good advertising to have the man carrying a cannister mask at all times so he remained at home until the 21st of April, three months after the injury. By this time escape masks had been located throughout the test area, and it was no longer deemed necessary for him to carry a personal mask.

On the 26th of April the cardio-respiratory laboratory of the University of California, San Francisco, reported that his lung function was within normal limits. He had no work intolerance at this time. In September 1960 he did have trouble driving his auto over the top of the

Sierra Nevadas because of shortness of breath, but has not been bothered since.

There was sporadic coughing throughout the night from the fifteen men under observation, but it subsided by morning except in the man who had been on the third level of the test stand. He had noted the lights turn yellow and saw men leaving the area so he went downstairs. He began to cough on the first level. He was having paroxysms of coughing and complained of dizziness and an irritated throat on arrival at the dispensary. At 11:30 P.M. he ate a sandwich and had prompt emesis. At 2:15 A.M. he complained of headache; at 3:00 A.M. he was coughing frequently. At 6:30 A.M. his temperature was 100.4. He had a sore throat, his chest was clear, and he was able to eat. He was sent home to return if necessary or at the start of the next day's shift.

At 11:00 in the morning he called and stated that he was very ill and could hardly breathe. He was brought in by ambulance, coughing continuously, not cyanotic. His pulse varied from 92 to 104. His temperature was 102, and his respirations varied from 48 to 60 per minute. On oxygen his respiration regulated at 48. He had a few very fine rales in the right base, otherwise physical examination was not remarkable. Chest X-ray done at this time (eighteen hours after exposure) showed diffuse disseminated generalized nodular densities in the lung parenchyma. He was hospitalized that afternoon. His white blood count was 18,000 with a marked left shift and a normal sedimentation rate. He was most ill 36 hours after the exposure.

Two and a half days after exposure the lungs were clear, and the chest X-ray showed some improvement. Five days after exposure, there was marked improvement. No X-ray change was noted then until the 9th day at which time the patient had a normal physical examination and a normal chest X-ray. Pulmonary function studies performed two weeks later were normal. He has remained asymptomatic since that time.

The other fourteen individuals were asymptomatic 24 hours after exposure, and their chest X-rays were normal and remained so.

Our subsequent two gas emergencies have resulted in no exposures to N_2O_4 . The alarms were sounded at the time of the gas release, and it was possible for down-wind personnel to don their cannister masks and begin evacuation of the area before the oxide cloud arrived.

Several things are pointed up by our experience. The men exposed were relatively close together and probably received relatively similar exposures. Yet only two clinical cases of lower respiratory tract disease appeared, indicating the variability of response so often noted previously. Early oxygen by mask rather rapidly alleviated much of the discomfort and apprehension. The patients should be kept under observation for 24 hours. Steroid therapy does reverse the fibrotic

stage of the disease. If we can get another case with a normal sedimentation rate and cold agglutinins we will treat the acute disease in the same way.

A personal communication from Dr. John Preston indicates that used on acute cases from a munitions plant the symptoms subsided quite promptly.

There is a great advantage possessed by people using Nitrogen Tetroxide in missile operations. They know at all times what they're handling. It is easy to demonstrate what the material looks like and smells like in air and to point out to them the necessity of performing their work with care. With proper training and close attention to the details of safe handling, the material should be no more dangerous than any other materials handled in industry.

There are several products on the market or in design which are aimed at continuously sampling for low concentrations of the oxides of nitrogen. Some of them are complicated; some of them are simple, but at the present time none of them work. It should be stressed that when development has reached a point where there is reliability in these systems, they should be used only as a back-up or, as an alert to indicate an area where a suspicious concentration of oxides of nitrogen is located. A man may then examine the questionable area.

Hunter D. Diseases of Occupations
Page 608 to 612-1955
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Health Hazards of Military Chemicals
Nitric Acids and Oxides of Nitrogen
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1959

Advisory Center on Toxicology
Oxides of Nitrogen
Report #114
National Academy of Sciences-National
Research Council
1961

We have used unsymmetrical dimethylhydrazine as a propellant for many years, and since January of 1956 we have encountered no problems in the use of the material. As with our other propellants most of the work is done out of doors, and therefore, exposures are limited in duration.

Since 1956, the substrate for UDMH, which is very damaging to the liver and kidney, has not been a contaminant in the material, and no difficulty has been experienced. Our people who work with UDMH have been examined in our clinical laboratory every six months, and no cases of liver or kidney disease have been discovered which could be attributed to handling the material. We at present use UDMH almost exclusively in a 50/50 mixture with hydrazine. This material is trademarked as Aerozene 50. It is a much safer compound to handle than hydrazine alone. The vapor phase consists of 92% UDMH with its very strong dead fish odor and only 8% hydrazine which is much less noticeable. We have had some burns of the skin due to hydrazine being in contact with the cutis, but not with UDMH which is readily soluble in water and washes off quite easily.

In general, toxicity problems in our plant have been confined to our research laboratories.

Our greatest potential hazard is in bulk fuel handling. In the case of the solid motors it is at the point where the raw materials are received, weighed and added to the mixer. From this point we are dealing with an homogenous mass whose cohesive properties prevent much in the way of loss of material. Engines using liquid fuels present no unusual industrial toxicological problems until they are ready to be test fired.

Considerable interest has been developed in recent months in an effort to determine the combustion products from firing rocket engines. The combustion products of a normal firing at a military base should be of little concern since the missile being fired would only momentarily be in the neighborhood. Even at static test stands, normal combustion products are of minor interest, since even under the worst condition of inversion and with tons of water being sprayed into the flame to protect the steel structure of the stand, the cloud rises rather than hangs on the ground. The cloud quickly rises to a high altitude and will dilute due to convection currents within the cloud. If, to complete the knowledge of missile fuel toxicology, the Air Force is interested in determining the identity and composition of combustion products, it is recommended that this be done at static test stands where the opportunity presents itself to collect a good sample, and that further investigation be conducted in a laboratory on combustion products produced under the less optimum conditions that would exist in a missile malfunction.

OPERATIONAL SURVEY OF A BOMARC SITE

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In the fall of 1959, the first of a series of Bomarc Missile Bases was placed on operational status. The initial Bomarc Missile was designated IM-99A. This surface to air interceptor missile is an expendable, pilotless aircraft designed for high altitude, supersonic flight. After vertical launch by a boost rocket engine, it is propelled through cruise and dive by twin ramjet engines. Guidance is provided by preset programmed command signals during climb, by ground command signals during cruise, and by homing radar signals during the dive and terminal phases of flight.

A Bomarc launch site will ordinarily consist of a launch area and a missile support area. The on-base Bomarc site receives such additional support as may be required from the host base. Ordinarily off-base Bomarc units will be satellited upon a nearby Air Force base for similar support.

Medical support for these sites is likewise supplied by the host base. Just prior to the activation of the first Bomarc site a staff visit was conducted by medical service personnel attached to Headquarters, Eastern Air Defense Force. The questions posed by this group instigated the initial preventive medicine survey made by the Air Force Medical Service for this type of weapons systems.

Some of the questions asked were as follows:

1. In what areas were health hazards to be expected?
What was the nature of the hazard and how was it to be controlled?
2. What was the composition of the exhaust gases of the rocket engines? What was the extent of diffusion of these gases and what was the hazard to personnel resulting from exposure to the exhaust gases?
3. What meteorological aspects were involved in the health hazards to be expected?
4. What type of instrumentation was needed to detect the air contaminants resulting from a Bomarc site operation?

The answers to these questions were not easy, for there was no precedence for them, nor had any medical implication with regard to operation been considered while the weapons system was being conceived and built. In order for you to understand the type of problems involved, it is necessary to describe a Bomarc site briefly and enumerate the chemicals used to operate and service the weapons system. As mentioned before, the Bomarc site consists of two main divisions - the launch area and the support area.

The launch area is the largest area of the IM-99A base and it requires the greatest degree of security. This area contains the missile launching shelters with the missiles in a "ready storage" condition, security facilities, air munitions storage, and one or more compressor buildings.

The Model II Launcher Shelter, typical of an IM-99A base and installation, is a single story structural steel and concrete masonry structure housing one missile. The large double doors open for launching and to permit ground handling of the missile into or out of the shelter. The roof of the shelter consists of two longitudinally-divided sections which slide open when the missile is to be launched. The shelter is air conditioned and contains equipment rooms necessary for maintaining the missile in a ready-storage condition.

The compressor building houses high pressure and low pressure air compressors, a helium compressor, and compressor control panels. The compressor building electrical substation provides transformers and switch gear for distribution of electrical power from the heat and power building to the compressor equipment and to the launcher shelter. Compressed air and helium are delivered by pressure lines to each of the launcher shelters.

A system of roads within the launch area provides access to the launcher shelters, air munitions storage, and connects the launch area with the missile support area. The launch area is completely enclosed by a security fence equipped with an intrusion alarm system. Violation of the fence is automatically reported to the security control and fire station located within the missile support area.

The missile support area, located adjacent to the launch area, is also enclosed by a security fence. Within this area are located the heat and power building, the assembly and maintenance (A & M) shop, the squadron operations center (located within the A & M building), and propellant fuel and decontamination facility, the fire station and security control building, and the weapon support equipment shop.

The heat and power building contains equipment for generating hot water for base heating and chilled water required for air conditioning and missile nose cooling during "ready-storage" and "warm-up" conditions.

The A&M shop contains the equipment required for the assembly, operational testing, and servicing of newly received, recycled, or mal-functioning missiles.

In addition to the main shop area are the major assembly test sets (MATS) area, the battery storage and testing rooms, and the ramjet engine testing and storage area. Other A&M shop areas provide for parts storage, service checkout equipment (SCE), mobile inspection vans, air and electrical equipment, office, spaces, and the squadron operations center. Spare missiles are stored in an A&M shop before transfer to the launch area whenever a missile is removed from a launcher shelter for recycling.

The propellant acid facility is the storage area for inhibited red fuming nitric acid (IRFNA) to be used in the Bomarc IM-99A. The IRFNA is dispensed to tank trailers which are moved to the launcher shelter where it is transferred into the missile. Propellant acid removed from a missile in the launcher shelter is transferred to a mobile trailer which is then moved from the launch area to the propellant acid facility. The acid is tested and stored if reusable; otherwise, it is stored for later disposal.

The propellant fuel facility is the storage area for JP-X Fuel, 80-Octane fuel and Aniline Furfuryl Alcohol (ANFA) used in the missile. This area also includes decontamination equipment. Fuel is received from transport trucks and stored in underground tanks and appropriate fuel is then pumped into JP-X or 80-Octane mobile trailers at the service area of the facility. Mobile trailers are then towed into the launch area to service the missile in the launcher shelter. Missiles that are to be subjected to a periodic recycle are defueled at the launcher shelter and towed to the propellant fuel and decontamination facility for decontamination. Decontamination equipment installed at this facility is used for purging the IRFNA, JP-X, and the 80-Octane fuel systems of the missile.

In addition to buildings and weapon control and support equipment described above, the typical IM-99A base has extensive communication and alarm systems. They consist of telephones (PBX, PAX); public address system; teletype system; launcher status circuit; missile status circuit; pre-launch command circuit; GAT (Ground-To-Air Transmitter) monitor circuit; digital data circuitry; compressor house monitor circuit; intrusion alarm circuit (previously mentioned); personnel alert system; and a fire alarm system.

Each system or circuit is essential to complete operational control.

Physically detached from the base, but an essential part of the weapons system is the GAT (Ground to Air Transmitter). GAT receives control signals from SAGE (semi-automatic ground environment) and transmits them to the missiles during flight.

SAGE, which may be located hundreds of miles away from the IM-99 base, assimilates radar information received from the air defense network. From the assimilated information, signals are transmitted by SAGE to the IM-99A base which results in launching commands being directed to selected missiles in the launcher shelter. After launching, the missile flight control is directed from SAGE through GAT located near the IM-99A base. So much for the description of a Bomarc Base and its equipment.

The chemicals used in the Bomarc Weapon System can, if improperly handled, present a serious health and fire hazard. Chemicals such as JP-X, JP-4, Unsymmetrical Dimethyl Hydrazine (UDMH), inhibited Red Fuming Nitric Acid (IRFNA), Hypergolic Fuel (Aniline-Furfuryl Alcohol, known as ANFA), Anhydrous Ammonia, and 80-Octane Gasoline are all flammable and/or toxic, and must be treated with respect. By being aware of the hazardous properties of these chemicals, personnel can better understand and appreciate the need for the care required in their handling and use.

JP-X Fuel is a mixture of JP-4 and UDMH. JP-4 Fuel is a kerosene aromatic hydrocarbon type fuel; the vapors of which are toxic and highly flammable. The concentration of JP-4 vapors which is harmful to health is much lower than that which may create an explosion or fire hazard.

UDMH is a colorless, hygroscopic liquid with a rather sharp ammonia-like or fishy odor. It is a strong caustic, and will attack the mucous membranes and skin anywhere on the body. Due to its high vapor pressure, it is absorbed through the respiratory organs at a much faster rate than through the skin. At high concentrations, the vapors of UDMH are quite irritating to the respiratory tract and eyes, which serves to limit acute exposure. At lower concentrations, the irritating effect of the vapors does not necessarily provide adequate warning during exposure, and the damaging effects can therefore develop some hours after exposure. When JP-4 is mixed with UDMH to make JP-X, the mixture presents the same toxic hazards as UDMH and the same fire hazards as JP-4.

Inhibited Red Fuming Nitric Acid (IRFNA) is a highly corrosive oxidizing agent which will vigorously attack most metals. It will react with most organic materials violently enough to cause fire,

and reacts explosively with many chemicals such as aniline, furfuryl-alcohol, gasoline, hydrogen sulfide, JP-4, UDMH, and xylidine. The fumes of IRFNA are extremely toxic and cannot be relied upon to give adequate warning of their presence to personnel.

Aniline-Furfuryl Alcohol (ANFA) is a mixture of aniline and furfuryl alcohol. Freshly distilled aniline is a clear, slightly oily liquid which gradually turns to dark brown upon extended storage. Aniline is considered very toxic by inhalation and by absorption through the skin.

Furfuryl alcohol is a light amber colored liquid which will react explosively with fuming nitric acid. It is a moderate health hazard by inhalation and some skin absorption can occur upon contact.

Anhydrous ammonia is a colorless liquid with a distinctive pungent odor. This material can cause severe skin irritation and burns upon contact, due not only to its caustic effect, but also to the freezing effect produced by its rapid evaporation. Anhydrous ammonia fumes give adequate warning of their presence and personnel will not voluntarily remain where these fumes are present. This gas, when mixed with air, particularly in the presence of combustible materials of oxygen and oil, may be flammable.

The hazards presented by these chemicals may arise from direct contact with skin or eyes, or by inhalation of the fumes or vapors. These hazards may include irritation of the eyes, nose, throat and/or skin, severe burns, internal illness, dermatitis, and even serious lung and heart conditions, depending upon the chemical and the length of time exposed.

To protect against the health hazards presented by these chemicals, personnel should wear suitable protective clothing and work in areas having adequate ventilation. In areas not having adequate ventilation, respiratory protection should be utilized, and for specific operations, may be required. Whenever respiratory protection is required, the proper type of respirator for the particular job should be used.

Pursuant to policy contained in AFR 160-20 and in response to a request from the Surgeon, Hq ADC, a consulting industrial hygiene engineer and industrial hygiene chemist were dispatched from the Kelly Regional Environmental Health Laboratory in the Fall of 1959 to observe operations, study procedure, take samples at the 46th Air Defense Missile Site.

The observations made during this survey took cognizance of the questions posed by the headquarters staff visit team. In addition all of the current operations in progression were observed and

evaluated with regard to prevalent or potential health hazards. Some of the observations and recommendations made were as follows:

1. Radar test tunnels located in the A & M shop should be checked for microwave radiation leakage. Test equipment for this purpose is available in the Environmental Health Laboratory.
2. Hydrocarbon vapors in the ram jet test cell should be determined during and after operation of the cell.
3. The acid fume scrubber is obviously not efficient enough to absorb nitrogen dioxide and tetroxide vapors at a very high rate. Environmental Health Laboratory personnel made laboratory studies to determine what scavenger agents could be added to the scrubber water to improve the efficiency of the presently designed installation. This appears to be the most economical method of increasing the efficiency of the scrubber so that it will satisfactorily handle the maximum acid vapor load possible emanating from the oxidizer storage tanks.
4. The thermal stresses imposed upon fuel handling personnel who wear protective suits should be determined during summer weather operation. This study should be accomplished by the medical personnel attached to the missile squadron.
5. Test corings under the UDMH leaching wells should be made at six month intervals after the missile base is placed into operation. This should be done to determine the infiltration of UDMH and Chromium salts into the sub-surface strata above the water bearing aquifer which furnishes the drinking water supply for the missile base. The coring should be accomplished by support base personnel. Analyses of the cores for UDMH can be accomplished by the Environmental Health Laboratory.
6. The emanation of X-rays from high power electronics into the control room at the GAT site should be determined. This can be accomplished using film dosimetry techniques.

7. As operating personnel will spend a considerable period of time in the decontamination building without wearing protective equipment, the UDMH vapor level should be evaluated carefully in this structure over a long period of time. This will probably have to be accomplished daily over protracted period of time by medical personnel assigned to the missile squadron.

Personnel exposure evaluation to fuel and oxidizers was made by Boeing Industrial Hygiene personnel during initial transfers of these materials. The field evaluation was made with direct reading type instruments. A summary of the results is as follows:

- a. Transfer of JP-X (containing Dimethylhydrazine) from commercial tanker to fuel storage.

Date: 8-5-59 Transfer time: 40 minutes
Time: 1740 Volume transferred 1900 gallons
Temp: 78°F
Wind Dir: 70°

Wind Vol: 10-15 M.P.H

The average concentration of UDMH determined in the breathing zone at 1 to 6 feet from the Tanker was 2.5 parts per million part of air (PPM). This concentration represents the exposure of the employee required to make and break the connection and oversee the transfer from the tanker to the storage tanks. A leak occurred at the tanker connection in which several gallons of JP-X were lost onto the concrete apron and were immediately washed down by the fire department. Direct reading samples obtained with the Mine Safety Appliance UDMH Detector showed concentrations ranging from 3 to 10 PPM during the leak and disconnecting from the tanker. The tanker trucker driver performed the connection, disconnection and repair of the leak. The JP-X vendor does not supply the driver with protective clothing or respiratory protection. These were provided to him by Boeing personnel.

- b. Transfer of JP-X from storage facility to Boeing trailer

Date: 8-10-59 Transfer Time: Approx. 11 min.
Time: 1930 Volume Transferred: Approx. 300 gals.

Wind Dir: 240°

Conditions: shelter doors
open

Wind Vel: 14 to 21 M.P.H.

Direct reading samples showed breathing zone concentrations to be consistently less than 0.5 ppm. At one time, during disconnect, a small spill gave readings from 3 to 7 ppm. The JP-X trailer fume scrubber appeared to function properly. No UDMH could be detected by odor or by direct reading through it. There was definite odor of the acetic acid from the scrubber.

Comments

The maximum allowable concentration for prolonged exposure (8 hours a day, 40 hours a week) to unsymmetrical dimethylhydrazine is 0.5 ppm. For normal transfers of JP-X at a Bomarc base it is not felt that significant UDMH exposures will be encountered. Employees should have organic vapor-ammonia cannister full face respirators immediately available to don in the event of a spill. The alertness of the fire department will serve to minimize UDMH exposures since the spills are immediately flooded with copious amounts of water.

It is the opinion of the observers that the odor threshold of UDMH is 0.5 to 2.0 ppm rather than 6 to 14 ppm as stated by many authorities. Direct reading and chemical determinations made when UDMH odor was present in the fuel facility would appear to bear out this opinion.

The Mine Safety Appliance UDMH detector appears sensitive enough to indicate air concentrations which would warrant the use of respiratory protection. It is felt that one of the fueling crew members should be equipped with the detector and checking the working environment at regular intervals during the JP-X transfers.

I would further recommend that the vent line from the JP-X facility be extended upward another 10 feet.

d. Transfer of acid from commercial tanker to oxidizer storage tank.

Date: 8-13-59

Rel. Humidity: 90%

Time: 2300

Transfer Time. Approx. 50 minutes

Temp: 78°F

Volume transferred: 2700 gals.

Wind Dir: 240°

Wind Vel: 7 M.P.H.

Temp: 75°F

Conditions: large south door
closed - all other doors open.

Wind Dir: 190°

Wind Vel: 5 M.P.H.

UDMH concentrations determined chemically in the breathing zone around the trailer were close to 3 PPM during the transfer. Direct reading concentrations with the UDMH detector ranged from 0-10 PPM. The 10 PPM was measured for several minutes outside the facility and 50 ft. downwind after transfer and during bleed-off of the nitrogen pressure from 30 to 5 psi from the JP-X storage tank. UDMH concentrations were less than 0.5 ppm during transfer of the JP-X into the waste retention tanks.

Date: 8-14-59

Transfer Time: 13 minutes

Time: 1600

Volume Transf. Approx. 300 gals.

Temp: 90°F

Conditions: All doors open

Humidity: 52%

Wind Dir: 135°

Wind Vel. 6 M.P.H.

Chemical determination in the breathing zone in the control room during transfer showed a concentration less than 0.1 ppm. Direct reading concentrations ranged from 0 to 7 ppm. The 7 ppm was recorded at 18° from a small leak which developed at the facility fitting to the hose. Following the transfer a definite odor of UDMH was noticed in the heating and ventilating room. A 10 minute chemical determination of 0.5 ppm was observed. Direct reading concentrations of 10 ppm were observed at the start of sampling and dropped off to less than 0.5 ppm at the end of 10 minutes. It is felt that the UDMH was entering the heat and vent room from the bleed-off line during pressure bleed down.

c. Fueling and defueling JP-X from trailer to IM-99A
Missile in Shelter.

Date: 8-17-59

Rel. Humidity: 50%

Time: 1100

Transf. time Approx. 20 min.

Temp: 91°F

Volume transf. Approx. 250 gals.

During this transfer two direct reading type gas detectors were used to measure nitrogen dioxide concentrations. Concentrations of nitrogen dioxide measured around the tanker and in and around the acid facility, including the storage tank vault were less than 1 ppm for all normal operations. At one point a small leak developed at the hose connection on top of the tanker and a concentration of 1000 ppm was recorded within 1 foot of the leak. Scott Air Paks were being worn by personnel repairing the leak.

During venting of the tanker pressure a visible cloud of acid fumes was given off through the scrubber stack. Air samples were taken in the breathing zone at distances from 50 to 200 feet downwind. A maximum reading of 5 ppm was obtained at 100 feet while the 200 feet distance showed 1 - 3 ppm. The venting required approximately 30 minutes.

At the time of disconnect of the hose from the tanker concentrations of 8 - 10 ppm were recorded 30 feet downwind.

e. Transfer of acid from storage facility to Boeing trailer.

Date: 8-14-59	Wind Vel:	6 M.P.H.
Time: 1800	Transfer Time:	25 minutes
Temp: 86°F	Volume Transferred	Approx. 600 gallons
Humidity: 50%	Condition:	all doors of facility open
Wind Dir: 135°		

During transfer of the acid from the storage tanks to the Boeing Trailer three separate air samples were taken with three nitrogen dioxide detectors, each made by a different manufacturer. For normal operations all breathing zone samples showed nitrogen dioxide concentrations below 1 ppm in the entire acid facility.

During venting of the pressure from the acid storage tank, concentrations up to 10 ppm were recorded at a distance of 75 feet downwind from the scrubber stack. The venting could be adjusted so that a dense cloud of fumes was produced or virtually no fumes at all. The vent valve was opened 3/4 of a turn and this produced "moderate" fuming and the conditions under which the above samples were taken.

The acid hose was drained and washed into the sump. The acid was released intermittently from the hose and each release produced "moderate" to "heavy" visible fuming from the stack. Approximately 1/2 gallon total was drained from the hose. Concentrations of 8-10 ppm were recorded at 50 to 75 feet downwind. Unfortunately the samples may have been collected too close to the stack for the visible fumes appeared to pass overhead about 15 feet.

During disconnect of the hose from the facility a small spill (several ounces) occurred. Breathing zone samples showed 5-10 ppm. The fireman promptly sprayed the spill with water.

While the acid retention tank was being vented samples at 75 and 100 feet downwind from the stack showed 3-5 ppm and 1-3 ppm respectively.

f. Transfer of acid from Boeing trailer to IM-99A in shelter #2-28.

Date:	8-17-59	Wind Vel:	10 to 16 M.P.H.
Time:	1900	Volume Transf.	Approx. 10 gals.
Temp:	89°F	Conditions:	shelter doors open

Wind Dir: 240°

Due to fitting and hose difficulties very little acid was transferred to the missile. When the leak developed at the fitting to the missile (and the acid pressure shut off) 1-3 ppm concentration of NO₂ was observed 3 feet downwind. During disconnect 20 ppm was recorded and this completed the operations until the hose and fitting problem would be resolved.

Comments

The maximum allowable concentration for prolonged exposure to oxides of nitrogen dioxide is 5 ppm. Concentration about 50 ppm should be considered serious for exposures which may exceed even a few minutes. Personnel should have self-contained breathing apparatus immediately available in the event unusual circumstances develop. It is evident that during normal transfer operations no significant acid gas exposures were recorded.

It should be remembered that the concentrations of acid gas measured downwind from the scrubber stack were for the particular set of atmospheric conditions at that time and do not necessarily mean that worse (or more favorable) results would be obtained under different meteorological conditions. A spill of any consequence in the acid

facility would mean considerable "fumes" emitted through the scrubber. Meteorological conditions might be such that significant NO₂ concentrations could be seen in the acid facility or change house.

With regard to the scrubber stack it is recommended that the cap be removed or built such that there is no impingement of the exhaust of the cap. This would give the stack an effective height of 5 to 10 more feet.

g. Transfer of aniline from drum to ANFA cart.

The atmospheric concentration of aniline in the breathing zone of the employee during this operation was less than 1 ppm. The maximum allowable concentration for prolonged exposure to aniline vapor is 5 ppm. It is not felt that this operation presents a significant hazard by inhalation. However, adequate precautions must be taken to prevent skin and eye contact with the fluid. No direct reading type instruments are available for aniline. One is not required on the Bomarc bases.

This initial survey pointed up the fact that the Preventive Medicine program at a Bomarc Missile site is a very important part of the normal operational procedures and must be conscientiously carried out continuously. In addition, it pointed up the fact that during the conception and fabrication of a new weapon system the medical aspects of operation must be carefully considered and the health hazards evaluated. A manual of procedures should be prepared in advance of operational status, so that the support medical service will not be completely in the dark as to what health hazard may be expected and how they are to be handled.

The recommendations contained in the report of the initial survey have all been carried out in some respect. Some of the answers are still wanting. Although attempts have been made to get qualitatively and quantitatively data regarding exhaust products of the Bomarc, this data is still meager and incomplete.

The survey also verified the fact that the industrial health problems confronting the engineer in the so-called space age are no different from those in the "Aeronautic Age." It may be perfectly O.K. for the rocket designer to keep his head in space but the industrial hygiene engineer had better forego such a treat because he would surely have to stretch a lot to keep his feet where they belong.

HEALTH HAZARDS AT A STRATEGIC MISSILE SITE

Capt John J. McCambridge
Hq 15th AF

I would like first to say that I'm going to confine my comments to three missile systems - the SM75, the Thor; the SM 65, the Atlas; and the SM 68, the Titan I. These are the three systems that the Strategic Air Command has now in its inventory, or which they helped make operational through training others who operate the missile.

The Thor is an intermediate range missile. It has a nominal range of 2500 nautical miles. The missile, although a strategic missile, is not operated by the Strategic Air Command. It's operated, instead, by the Royal Air Force of England. The crews for this missile, however, were trained at Vandenberg AFB. They received their crew training there, they did their proficiency launching there, and they return there periodically for proficiency firings. The program is under the surveillance of the Strategic Air Command.

The Atlas was our first truly Intercontinental Ballistics Missile. This has a nominal range of 5500 nautical miles, although, as you know, they have been launched for much greater distances from Cape Canaveral in experimentation greater than 9000 miles. The Atlas will be stationed at such bases as Francis E. Warren, Fairchild, Schilling.

The Titan I, the SM 68, is also an Intercontinental Ballistics Missile with a nominal range of 5500 nautical miles. The Titan I will be stationed at such bases as Lowry, Ellsworth, Mountain Home, etc.

Slide No. 1

This is a Thor Missile, the type that is currently stationed in England. The launch area you see here is at Vandenberg AFB, out at what is known as "The Point." This is the same area from which the Discoverer Satellites are launched. These, as you know, use the Thor missile as a booster. The missile is stored in a horizontal position and at the time of launching is raised into the vertical, fueled and then launched. This is not a mobile system, but is rather a transportable system; the philosophy behind this being that the entire missile with its support equipment can be loaded upon aircraft - not one aircraft, but several - and transported to a different site. The only thing that would then have to be constructed at the site would be the launch pad itself. The mobile equipment you see within the concrete shelter in the picture. On the left, the left-hand bays contain high pressure nitrogen trailers containing gaseous nitrogen, about 2500 pounds per square inch. There are also contained within this shelter

electrical sub-systems, hydro-pneumatic trailers, and other checkout equipment. At Vandenberg this missile would be launched from a blockhouse. At the operational site, however, the launch equipment is contained in just one more trailer, so it too is transportable.

Slide No. 2

This is an Atlas Missile. The Atlas Missile is designed in several configurations. We have at Vandenberg one complex of vertically stored and launched missiles. These are similar to the classical gantry crane or surface tower used at Cape Canaveral. Most missiles at Cape Canaveral are in a vertical configuration in a gantry.

At Vandenberg, however, and within the Strategic Air Command, there is but one complex of this nature. The others are all stored either horizontally or in a silo. This particular complex you see here is what we call a "coffin" configuration. This missile is stored horizontally in the white concrete "coffin" at the lower right hand portion of the picture. Prior to launch, the missile is raised to a vertical position with that yellow lattice-work as the support structure. After it reaches to the vertical position, the "O" ring at the top of the missile is loosened, the lattice-like structure is moved back an additional 15° and after fueling the missile is ready to launch. Other Atlases coming on at a later date will be stored in a silo in the ground. The two large blue tanks you see are liquid oxygen tanks. These contain liquid oxygen at a temperature of 297° below 0° Fahrenheit.

Slide No. 3

This is a photo of the Titan I being elevated out of its silo. Those doors in the picture weigh in excess of 100 tons. This missile, as do the other two missiles, uses liquid oxygen as an oxidizer and RP-1 as a fuel, and is stored in an underground configuration and then raised to the surface and launched. As you know, follow-on missiles will be launched from the silo.

Slide No. 4

All of these missiles can be described in general, in some ways. They all have propellant systems, they all have guidance systems, they all have a re-entry vehicle. They have hydraulic and electrical sub-systems. They all present a group of problems of interest to us in the Medical Service which are similar one to the other except for individual differences. We have propellant problems, radiation problems, both ionizing and microwave. There are noise problems, which unfortunately exist,

although perhaps they should not at this date. There are survival and efficiency problems of people, living in remote locations, or in test operations at Vandenberg, being involved in operations hazardous at the time they are undertaken.

Slide No. 5

In addition to this, the very configuration of strategic missile squadrons throughout the country gives us some problems in itself. Our missile launchers are not based on SAC bases, neither are they independent installations apart from the aircraft bases. They are all, without exceptions, located around the periphery of an active Air Force Base. Now, I'm speaking of Atlas and Titan. They use this active base as the support base. The distance between the complexes and the support base may vary anywhere from 10, 12, up to as far as - although this slide says 50 miles - in the Lowry and Warren areas they go almost as high as 70 miles. This of course, as you can see, is both a maintenance and logistics problem to the operational people, and a surveillance problem to the Medical Service.

Slide No. 6

These remote locations in themselves occasion problems of boredom and fatigue among the people working at the complexes, and in some cases there will be but two or three men on a crew, and they may be there for 24 hour shifts, and we are even experimenting with as high as 60-hour shifts. Of course, they will have time to sleep in between. The human engineering problems are manifold, and we will get in to them a little later.

Slide No. 7

At the launch emplacement itself we have a launch pad or a silo or a "coffin", the actual facility in which the missile is stored and from which it is launched. We also have propellant ready-storage areas where the fuel and the oxidizers are stored. In some systems, the fuel will be pre-stored upon the missile, and only the oxidizer must be loaded prior to launch. There are also guidance antennae for the radio inertial systems. We have inertial systems which are completely devoid and independent of the ground guidance, and then we have radio inertial systems which are dependent for an initial part of the trajectory on ground guidance. There is also a control center, a blockhouse, an LCC (launch control center, as it is called) in which are located the consoles that control the launch of the missile.

Slide No. 8

Back at the support base will be the maintenance area - the MAB, Missile Assembly Building. All of the systems have different

names for this aircraft hangar (that's all it is, a missile hangar). Some call it the G-NAB (guided missile assembly building); others call it the MAB (missile assembly building) but in any event, it is the maintenance hangar. There will also be a liquid oxygen and liquid nitrogen generating plant, usually 25 tons. At Vandenberg there are two plants, twenty-five tons per day and fifty tons per day, a total capacity of seventy-five tons per day of liquid oxygen and liquid nitrogen.

Also, and this is something often overlooked, we still have the mundane, so to speak, problems of an ordinary Air Force Base. We have personnel facilities; we have recreational facilities; we have a base water supply; we have dependent medical care problems.

These must be accomplished simultaneously with the accomplishment of the support of the missile operation.

Slide No. 9

We have found that the Industrial Hygiene Engineering principles and the Occupational Medical principles that are required in the support of the missile program are no different than those already well proven in the aircraft industry and civilian industry. There are those groups within the Air Force that like to make the missile business something so special and different that it requires a complete change of philosophy and a complete change of names. We have found this is not so. We have operated at Vandenberg since 1958 and subsequently in the 15th Air Force with the same people and the same procedures that were used with the aircraft force.

Slide No. 10

The same principles apply. Again, being that the missile business is new, being that it is a number one priority project, many people have attempted to overplush some of the missile facilities. SAC, of course, does this in the Aircraft force with the alert crews; they attempt to give these people something extra. The attempt is also being made in the missile business. Well, we support this as far as it is economically feasible, but in the aircraft alert force we are speaking of a small group of people at any one time. Perhaps we would have to provide plush facilities (standby facilities) for 5% of the total assigned force. If we expand or extrapolate this same philosophy to the missile business, we will eventually have to provide these facilities for the entire force, which of course we cannot do.

Slide No. 11

Now as for the fuels that are used, or are in contemplation to be used in strategic systems or in the satellite systems that are launched from Vandenberg, we have liquid hydrogen, unsymmetrical dimethyl hydrazine, which Dr. Clancy has already discussed, hydrazine, aeroxine 50 which is a combination of the two and RP-1 which is nothing more than a kerosene fuel. Among the oxidizers we have liquid oxygen and inhibited red-fuming nitric acid. We also have high pressure systems, both nitrogen and helium up to from six to eight thousand pounds per square inch, on some of the launch emplacements.

Slide No. 12

I will not go into this, because there are others here who will speak more fully on fuel problems, but this chart gives you a rundown of the maximum allowable concentrations for some of the fuels that are being used, just to give you an idea of the chronic toxicities of these materials and the Medical evaluation that is being currently undertaken at First Strategic Aerospace Division at Vandenberg.

Slide No. 13

On the next slide we have the same information for the oxidizers. I might say here, and I think it may have been brought out by another speaker, and will probably be brought out later, that although we have, and have had for quite some time extensive information on chronic toxicities of these materials, we are lacking, or have felt we have been lacking, in good data for acute exposures. This is what, in the operational end of the business, we are more concerned with. We are more concerned with the accident where we have to send the man in for a short period of time into a high concentration.

Slide No. 14

Now of course, we also have noise problems, and these, unfortunately were identified in the design stage; the potential, that is, was identified, that these problems would exist. We have power generation facilities. Each one of these missiles requires a significant amount of power, so they all have their own power generation facilities. These facilities by their very nature create high sound pressure levels. This was pointed out (someone asked about who's reviewing these things in the design stages.) Well, this was pointed out in the design stages of some of these missiles, but for some reason, whether it was economy or other considerations, they apparently were not considered at the time because we do have, at the present time, noise problems.

Slide No. 15

We are not only concerned with noise levels that are considered injurious to health, those are outlined in AFR 160-3, but we are also concerned in SAC with speech interference levels, that interfere with communications between operations personnel at the consoles. Now you may say that this is not the Medical Service's responsibility, but it really is, because safety is compromised here if communication is not good; secondly, we are the people within the organization that are supposedly the noise experts, so we are the ones who are called upon to provide the professional guidance in obtaining acceptable speech interference levels in our launch facilities.

Slide No. 16

I don't know if all of you can see this picture. This is a picture of an Atlas powerhouse. This is one specifically in the 576-A complex at Vandenberg. Overall sound pressure levels in here are in the neighborhood of 105 DB. This is our lowest, really, of the missile systems. Two people work in this area, and hearing protection is, of course, required.

Slide No. 17

I would like to point out here that I'm only going to mention overall sound pressure levels. We are aware that the octave band analysis must be performed and this is really the criterion, but here, for the sake of simplicity, I will just mention overall sound pressure levels. This is the TF-1 Titan powerhouse, again at Vandenberg; this is the powerhouse of the complex, where the explosion took place about a year ago. This powerhouse was not damaged, however, and is currently being used for another silo, another launch area. This is the powerhouse that provided the power for the launch of the Titan missile about a month ago, the first successful demonstration launch from Vandenberg. This is also probably our noisiest powerhouse. Overall sound pressure levels in here range up to -- well, they have ranged between 115 and 118 decibels. We thought we had a pure tone here because we did, according to the criteria of 160-3, but we had Dr. Parreck from Wright-Patterson up to visit Vandenberg recently, and Lt Silva and Lt Carter told me that after taking half octave bands and fractional octave bands, he decided that he did not have a pure tone. In any event, the sound levels themselves are extremely high. Now in addition to the hazard to the hearing of the personnel here, they are required to communicate, by electronic communications equipment headset, with the launch control operator who is in a different building. The original headsets that were ordered and installed in this area were useless because the communication over the phones could not be understood by the LCO because of

the noise level. There was also a telephone, a very nice telephone, that was installed on one of the pillars there right smack in the middle between the generators. It can't be used at all. In any event, here we have recommended the use of sound protective helmets with integral communications equipment. Also, there has been considerable effort over the past year to have Ballistics Systems Division put some acoustic treatment in here, and after about a year and a half of fighting we thought they had accepted it; now they decide they don't have any money and SAC's going to have to do it with their own O & M money, which I imagine we will do.

You have seen these power plants, that I've just shown you, which are fixed in placed buildings. These are for Atlas and Titan. Now the Thor mobile system had its power generated by power generators installed in these mobile trailers. Each one of these has a 250 HP 550 KVA diesel generator. There were four per complex for three missiles. These, of course, can be air transported. The sound levels, inside, were about 107 DB over all. Fortunately, only an hour per day of operation was required, in which a man's presence was required within these trailers. This system is now under the surveillance of the Royal Air Force.

Slide No. 18

This is the exterior of the liquid oxygen generating facility. The sound pressure levels in here, depending upon the cycle of operation, can range up to 122 DB overall. This is a hazardous noise area, requiring the use of muffs and plugs, both.

Slide No. 19

This is an Atlas pumphouse which again is only operated part time and requires only the use of protective equipment while the individuals are in the area.

Slide No. 20

This is the hydraulic servicing unit, which is part of the Atlas system. This unit, one per complex, is used for checking out the hydraulics and the pneumatics on the Atlas. This is operated one hour a day per site by the hydraulic repairman. However, the same man on a three-missile site must go around and operate each one an hour apiece, resulting in a three-hour exposure. The exposure here is 104 DB at the front of the panel and 108 at the back, because the back is open. This again occasioned a communications problem as well as a hearing conservation problem in that this man had to communicate with the launch control operator back at the

Launch Control Center. When we first encountered this problem the operator (he must report the readings on the gauges to the LOC as the unit is operating) was reading the gauge and running behind a pole over here behind a partition in order to communicate back to the Launch Control Center because he couldn't be heard over the din. This is another area in which helmets with integral communication systems are required.

Slide No. 21

This just shows you the three types of protective equipment we are using - plugs, muffs (fluid-filled muffs, we feel are the best of the available types) and in the lower center the sound suppressive helmet with integral communications.

Slide No. 22

Now we have radiation problems too, both ionizing and microwave. One cannot speak of radiation without immediately thinking of the general concern around the world these days about radioactive problems. This is brought forcefully to our minds by the new dress that they have designed over in France. It's a new, low-cut French dress called the Atomic dress 40% fallout. We're going to discuss here together the ionizing and the microwave radiations just for the sake of simplicity. We are well aware that the effects are different; ionizing being the ionization of atoms, and microwave being chiefly a heating effect, and I believe Colonel Boysen is going to speak further on microwave radiation.

Slide No. 23

In the guidance control of a radio inertial system, we have both types of radiation. We have the microwave coming from the antenna, and we have X-radiation coming from the klystron, magnetron and thyratron tubes in the electronics within the building itself. Now, some of you may have read the paper by the University of Rochester describing an accident at the General Electric plant at Schenectady, I believe it was, where several people tried to perform maintenance on the back of one of these cabinets and were exposed. In SAC, so far, we have had no exposures whatsoever, no readable exposures on film badges from the X-radiation.

Slide No. 24

The MOD-3 guidance which is currently installed at three of our atlas bases, does have a microwave spectrum in excess of the 10 milliwatt per square centimeter allowable out to 150 feet

in front of the antenna, but this, of course, is quite directional - it has a cone of dispersion of only about 10°. Again at Vandenberg, this particular site is so oriented, that no one occupies this area in front of the antenna. I would like to point out a problem here. We have to my knowledge, no criteria for acute exposures to microwave radiation. This 10 milliwatts per square centimeter as I understand it, was rather arbitrarily arrived at and is an across-the-board figure. We do not have any time-concentration method of increasing this value for short periods of time. This is something that I'm sure we would all like to see worked out.

Slide No. 25

This is the back of one of these cabinets wherein the X-radiation might be received were the shieldings not to be in place. The cabinets are well-shielded so that you get no readable or detectable readings outside the cabinets.

Slide No. 26

In the missile itself, from a radiological standpoint, we have the re-entry vehicle, which contains the warhead. We have Thorium Magnesium Alloy, in the transition section of the Titan missile. This presents no external problems, Thorium being an Alpha emitter, but it would be a potential problem were any machining to be done on this material. SAC does not do any. This is all taken care of by others, so this really is no problem to us. We are aware of it, though. We also have Krypton 85 batteries in the system, Krypton 85 being a radioactive gas. People that actually handle these batteries are monitored with chest film badges, and wrist film badges, because the exposure, or rather the intensity of radiation at the surface of these batteries can be between 30 and 40 MR per hour. It decreases very rapidly with distance from the batteries, and they are not required to be handled continually, just periodically.

Slide No. 27

This is a picture of a re-entry vehicle on a re-entry vehicle transporter.

Slide No. 28

This is an APCHE console. Colonel Peterson was giving me the business yesterday about the SAC initials; we've got initials for everything. I found out, by the way, the other day that the name for one of these series of initials that form a new word is an acronym. I never knew that before. An acronym. The acronym for this piece of equipment is an APCHE, meaning Automatic Programming and Checkout Equipment. This is a piece of equipment, a console, with it's associated

electronic cabinets with which the entire missile system can be checked out in a time of about four hours, whereas it would take them about 48 hours to do it manually. They use decks of plastic cards with printed circuits inserted into this console in order to perform various electronic checks. These cards being plastic can pick up static charges. Were these cards to be inserted into the console with a static charge, there would be interference with the pick-up of the circuit. Therefore, a polonium-210 static illuminator bar is placed at the aperture (actually there are two, one above and one below) between which the plastic cards are inserted.

Slide No. 29

Each of these bars contains 1-3/4 millicuries of Polonium-210. This is an alpha emitter, primarily, and ionizes a layer of air about one inch above the bar. As the plastic card is passed through this ionized air, the static charge is removed, thereby allowing a clean pick-up of the printed circuit. These are required to be swiped. We initially wipe-sampled them once a week before we had any good information on them, and now we have decreased this to once every ninety days. There has been no problem with these bars, with the exception that at Warren Air Force Base they have had a few incidents of cracked bars. Lt Rothman just sent me the other day a complete resume of the instances they have had, which have been about three cracked bars. However, there have been no contaminating incidents. It's a low level, we appreciate that. These bars never become the property of the Air Force. They remain the property of the manufacturer, Nuclear Products, Inc., and when they decay, (their half-life is about 138 days) they decay to such an extent that they become ineffective, they are repackaged and forwarded under the ICC regulations back to the manufacturer.

Slide No. 30

In addition, at our installations, since there is a significant amount of construction, there is a significant industrial radiography operation. The contractors, after completion of complexes, valves, piping, etc., X-ray or radiograph these facilities to identify weak walls, stress concentrations, etc. They use either portable X-ray machines, usually 140 KV, Cobalt 60 or Radium 192. We have had sources as large as 50 curies on Vandenberg and on some of the 15th Air Force Bases.

Slide No. 31

For those operations involving radioactive materials that are directly within our control the Industrial Hygiene Engineering

Section provides surveillance. For those that are under the control of the contractors, we insure that they follow the necessary precautions in accordance with the NBS handbooks.

Slide No. 32

There are other situational stresses which are not necessarily engineering in nature, but which border on the human engineering aspects of the problem.

Slide No. 33

We divide these into those that are extrinsic - those coming from without the individual. There are multi-colored displays with green, red, yellow and white lights. Some lights blink, some don't. The operators must monitor these and must be able to readily and immediately identify a malfunction if a yellow light should turn red when it is supposed to be yellow; or if a steadily illuminated light become a blinking light, the operator must readily identify the malfunction. So these people are under some strain.

Slide No. 34

Also there are stresses from within the individual, the pressure to accomplish his task, the long hours which I have already mentioned. A 24-hour tour is what we are apparently shooting for now; it's still in a state of flux but they are experimenting with tours up to as long as 60 hours. Now, in order to alleviate some of these tensions, a lot of work has been done, not solely by engineers but by other allied fields, and they were trying to find a system that would reduce this emotional stress. They finally came up with a gadget -- a system and a gadget time proven and well constructed. It weighs about 115 pounds. (Slide of a bathing beauty.)

Slide No. 35

In addition to those normal routine activities, we also must remain ready to cope with any accidental situation that may occur. An explosion during a dual-propellant load, a broken arrow incident, which is an incident involving a nuclear weapon, or accidents resulting in multiple casualties. This is the disaster-control part of our function.

I'd like to say in conclusion that my purpose here today was just to review a series of facts about some of the experiences we have had. I don't feel qualified to give this group a message of any type, yet I can't leave the subject of health hazards in missile operations without making one comment.

All of these problems require the professional attention and decisions of professional people; i.e., engineers and physicians. Whether they be working as a team or not, their professional attention is required. They are therefore Medical Service problems. We have within the Air Force, outside of the Medical Service, groups whose interests in the health and welfare and safety of personnel parallel ours to some extent in some areas. Although these interests parallel ours, unfortunately their competence does not necessarily go in the same correlation. I would like to exhort everyone, or suggest, that all of us in the field make every effort to actively assume these Medical Service responsibilities. Not passively, but actively. Don't wait to be called; go and find out. These problems exist, and they exist everywhere, not just in missiles; go find out who is taking care of them if you're not. Somebody is, and it may be somebody not qualified to do so. I would also like to exhort those senior people here who are in positions to influence manning and space authorizations to recognize these problems, that they are Medical Service problems, just as much as dependent outpatients and that we need people to discharge these responsibilities. I think the alternative to this is the leaving of the Air Force and its problems to solution, or attempted solution, by incompetent people.

ATMOSPHERIC GASEOUS DIFFUSION

George H. Milly, PhD
Scientific Director
Army Chemical Center, Edgewood, Maryland

It is not my intention today to produce a complete do-it-yourself handbook covering micrometeorology and the behavior of toxic clouds arising from missile processing operations. In the time available for this subject, I will only attempt to give some feeling for the nature of the effects of meteorology and perhaps indicate some of the techniques that can be of assistance. Currently available information on diffusion and the behavior of clouds in the atmosphere has not, to my knowledge, been specifically applied in your areas of interest. Although one occasionally sees a discussion of applications to real problems, more often than not these relate to community or industrial air pollution situations. As I have thought about some of the factors which might be of interest to this audience, it has seemed to me that there is probably much that can be done with the available information on diffusion were it to be directed at some of your problems. I will try to point out some of the cases where useful solutions and conclusions can be developed.

With such a mixed audience, it seems desirable to devote a few minutes to discussing some of those aspects of meteorology which are dominant considerations in regard to cloud safety problems.

A most important feature is the turbulent structure of the wind. By turbulent structure I mean the irregular boiling and mixing of air as it moves over the earth's rough surface, which results in dilution and ultimate diffusion to harmless levels of materials released into it. One perceives this variability as fluctuations in the wind direction and wind speed, i.e., as gustiness. The fluctuations and variations occur over a wide spectrum of scale. The high frequency, low amplitude fluctuations, involving eddy sizes of small dimensions with respect to the size of the cloud being diffused, are the effective turbulent diffusing forces. There are also present larger eddy sizes, that is, lower frequency fluctuations which are large with respect to size of the cloud and result in a shifting and meandering, or irregular motion of the cloud as a whole. Clearly both of these aspects are of interest. The first, related to diffusion, determines how the concentration falls off as the cloud is mixed with fresh air during travel after release into the atmosphere. The other problem, concerned with low frequency components of variation exhibited by shifting wind speeds and direction, are of concern in attempting to define the path of the cloud and hence the areas, points, or people, that will be influenced by it, and the time history of these events.

The turbulent structure of the atmosphere is not ordinarily measured in the usual weather station, primarily because it is a feature of highly specialized interest which is not economically justified as yet in normal observational programs. As a consequence, unless special provisions are made for observations suited to your kinds of problems, you will not be able to get information related to turbulent structure from the records. Various indirect techniques have been devised to aid one in making estimations of the degree of turbulence from the normal observations. Several such techniques rely on the fact that the degree of turbulence is highly correlated with the vertical distribution of temperature and hence the vertical distribution of density. Although there has been extensive publicity concerning inversions in regard to air pollution, I think perhaps a little clarification of the notion of inversion might be helpful. One tends, I believe, to picture an inversion as a layer at some level above ground which acts as an impenetrable cap to bar the vertical transport of material upward. Inversion, going back to the origin of the term, actually means that the normal change of temperature in the atmosphere is inverted. The usual or average situation is one in which temperature decreases upward. Now, clearly, one can picture a temperature increase extending to varying heights before the normal decrease with height begins, and one can also visualize varying intensities of such inversions. One may also, and does, observe multiple inversions, one above the other. One may have an inversion, let us say, at a thousand feet and extremely unstable conditions beneath the inversion from the ground upward, with extremely thorough mixing in this region. Clearly, there is an important practical difference to those of us concerned with the release of toxic materials if the inversion is low and extends to the ground, so that the total layer in which the emission occurs is itself stable, and the case where the inversion occurs at 500 or a thousand feet with complete mixing beneath. In the latter case, a large volume of air is available for the rapid dilution of contaminants.

I mention these differences to indicate that one must give a little more thought to representing meteorological effects than defining a few simple categories of conditions in which to catalog the situations which you might encounter.

Despite the many possible complications, it may be useful to consider the average course of events through a 24-hour period. This is not only an average but probably a modal situation as well, in that it is the one most frequently observed, although there are important exceptions. The diurnal variation may be considered to begin at sunrise on a typical midsummer day with clear skies. Heating of the earth's surface, transfer of heat to the air and consequent production of low density air layers next to the ground, result in an increasing amount of turbulence during the course of the day which then dies out after sundown when the source of energy is no longer present. During the night the earth's surface is the effective radiating source and the locus of lowest temperatures.

Hence, there is a tendency to form the so-called nighttime radiation inversion, which increases in intensity and height during the night as additional cooling occurs. The picture just described is fairly typical for low wind speeds or calm conditions. If, however, the wind speed is moderate, say 8 to 10 miles per hour or greater, the roughness of the earth's surface promotes mechanically induced turbulence which, in effect, forcibly mixes the air, regardless of temperature stratification, and the net result is to reduce whatever temperature gradient might otherwise be observed. So, during the daytime, with increasingly high winds the temperature gradient observed will be more nearly isothermal. Similarly, at night the low level inversion will be destroyed due to forced vertical mixing of the air and consequent equalization of density differences.

Now, one can go beyond these elementary diurnal variations and consider other aspects which act to modify the idealized picture. There are nearly always features of the location, topographic factors, or other influences which lead to more complex variations. You are probably familiar with some of the more important ones: the occurrence of local wind effects due to topographic influences, the land-sea breeze due to differential heating effects. These, and other factors, need to be considered in any attempt to predict the stability regime. The development of some stability situations may induce wind effects which then oppose further development.

Another important aspect to be considered is the geometry of the source. The literature commonly treats point sources because this is the easiest kind to handle mathematically. In practice, one almost never encounters a true point source. The sources actually observed are usually some sort of volume or area. Occasionally, the source may be represented by a line. Examples of these: a volume source is produced when an explosion occurs. A vertical line source may be approximated by a break in a line which results in liquid falling from the break to the ground, evaporating as it falls. Area sources may arise by evaporation from a large spill on the ground.

At the moment, the important fact to recognize is that diffusion may be highly dependent on the relation between the vertical geometry of the source and the corresponding vertical distribution of stability. If we recall the earlier comments about some of the features of inversions, we can almost intuitively see how, when an elevated release occurs within a very stable layer, the natural tendency will be for the fume to move at the level at which it was emitted. Being in a stable layer, it will diffuse vertically very little. Under appropriate conditions, plumes have been observed to travel for tens of miles without ever reaching the ground surface.

If such an emission should continue for a period of hours, a long trail of contaminant is produced overhead. At dawn, insolation of the surface occurs, with mixing developing upward until finally the mixed layer

reaches the overlying stratum of contaminant and rapidly diffuses it to ground level. This phenomenon has been called a fumigation and serves to emphasize the necessity for considering some of the geometric aspects in the prediction of concentration fields downwind.

With the foregoing qualitative considerations in mind, I would now like to discuss briefly the quantitative treatment of atmospheric diffusion. It is not necessary to review the various theoretical approaches since these have been adequately discussed, e.g., Meteorology and Atomic Energy (U. S. Weather Bureau and U.S.A.E.C.), and the Handbook of Air Pollution (Magill, Holden and Ackley.) These books summarize a number of well known papers in the literature. Additionally, the entire problem is again being reviewed and summarized in a new report to be issued by the World Meteorological Organization within the next year.

The available mathematical treatments provide reasonably good approximations for certain idealized conditions. However, the mathematical complexities that enter when one extends the scope of the problem to include some of the realities to which we alluded earlier, lead to severe difficulties. Such solutions, therefore, are not readily available. I think that possibly this is the most important caution that I would like to sound today. We all know of Sutton's formula, and there are alternatives which can be used, but you will find they are all developed for infinite, homogeneous, flat terrain, a uniform surface, steady state and homogeneous meteorological conditions, simple source geometry, and so on. And when one speaks of the reasonableness of predictions obtainable by these equations, it is with these reservations in mind. This is not to say that the techniques cannot be usefully applied to the more complex real world problems. It does mean, however, that use of these formulae in some of the more complex situations, without cognizance of their limitations, is a questionable procedure. Later I will indicate how it may be possible to circumvent some of these limitations. At the moment, however, in order to impart an appreciation of the capabilities of current diffusion methods, I would like to summarize for you some of the results we have obtained in the Chemical Corps for the more or less idealized situation.

Instead of Sutton's formula, we have employed a more general mathematical formulation which expresses an assumption that there is a normal (i.e., Gaussian) distribution of concentration in each dimension, as follows:

$$X(x,y,z,t) = Q \frac{1}{\sqrt{2\pi} \sigma_x(t)} \exp\left\{-\frac{(x-ut)^2}{2\sigma_x^2(t)}\right\} \frac{1}{\sqrt{2\pi} \sigma_y(t)} \exp\left\{-\frac{y^2}{2\sigma_y^2(t)}\right\} \frac{1}{\sqrt{2\pi} \sigma_z(t)} \exp\left\{-\frac{z^2}{2\sigma_z^2(t)}\right\} \quad (1)$$

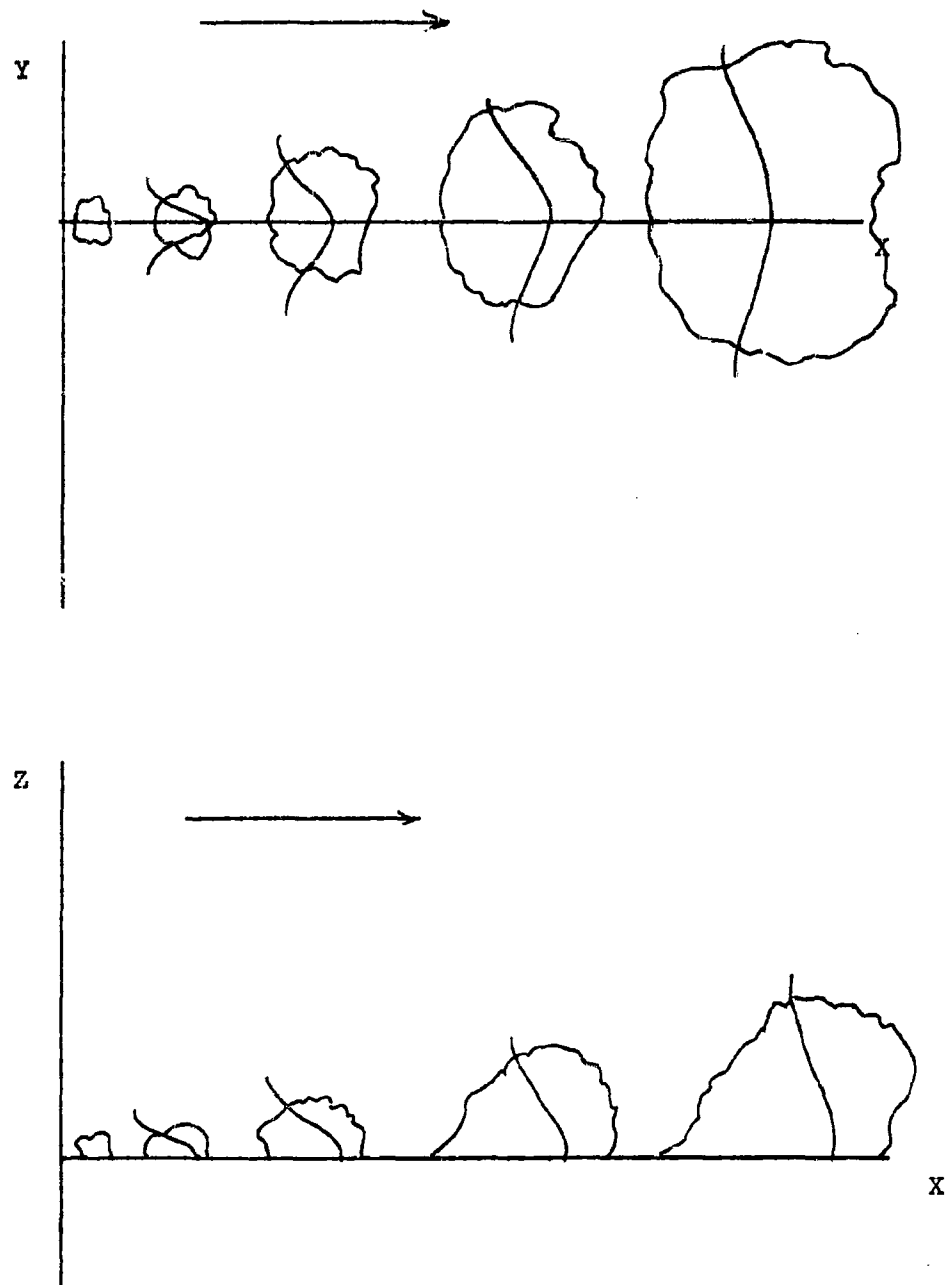


FIGURE 1. Increasing standard deviation with cloud growth.

where u is the mean wind speed, x, y, z , are space coordinates measured downwind, acrosswind and upward, respectively, t is time from release, and Q is the amount of material released.

If one examines Sutton's formula, it will be found that time, although there are several parameters with assigned physical meaning, the formula is nevertheless equivalent to the assumption of three-dimensional normality. This feature of the distribution of concentration is illustrated in Figure 1. Since the standard deviation is a measure of the spread of a normal distribution, it is clear that its value must increase with distance as the cloud travels and grows under the influence of diffusive forces. We have, therefore, analyzed field data to determine how the standard deviation increases with distance under various kinds of situations. In order to simplify the problem, the analysis has been done in terms of total dosage, defined as follows:

$$D = \int_0^{\infty} X dt \quad (2)$$

The solution for dosage may be obtained by making the appropriate integration of Equation (1), which with some approximations, gives

$$D(x, y, z) = \frac{Q}{\pi \sigma_y(x) \sigma_z(x) u} \exp \left\{ -\frac{y^2}{2 \sigma_y^2(x)} - \frac{z^2}{2 \sigma_z^2(x)} \right\} \quad (3)$$

This result states that the dosage at point (x, y, z) is equal to a quantity which contains the product of two normal distributions with parameters $\sigma_y(x)$ and $\sigma_z(x)$. These are the standard deviations laterally and vertically which characterize the size of the cloud at downwind distance x . We have found from experimental data that these standard deviations can be represented as power functions of distance:

$$\begin{aligned} \sigma_y(x) &= \sigma_y(x_1) \left(\frac{x}{x_1} \right)^{\alpha} \\ \sigma_z(x) &= \sigma_z(x_1) \left(\frac{x}{x_1} \right)^{\beta} \end{aligned} \quad (4)$$

where $\sigma_y(x_1)$ and $\sigma_z(x_1)$ are experimentally determined values at some reference distance x_1 , usually taken to be 100 meters. From Equations (3) and (4), it follows that, in order to make computations, values are required for the parameters $\sigma_y(x_1)$, $\sigma_z(x_1)$, α and β . Further, numerical values of these parameters must be related to some observable aspects of the ambient meteorological conditions.

We have found from a large number of field trials with the nerve gas, GB, that the parameter values were best correlated against atmospheric stability, where stability is measured by the vertical gradient of temperature between 0.5 and 4 meters. The values derived are summarized, as follows:

TABLE 1: POINT SOURCE DIFFUSION PARAMETERS

Temperature Gradient ($T_{4m} - T_{0.5m}$)	α	β	σ_y (100m), meters	σ_z (100m), meters
Lapse (-2°F)	1.86	1.86	3.41	25.00
Neutral (0°F)	0.88	0.88	3.41	5.85
Inversion ($+2^\circ\text{F}$)	0.66	0.66	3.41	3.85

With these values and the preceding formulae, one can make calculations for several temperature gradients. You may recall that Sutton's data permit estimates only for the neutral case. Our evaluation of the parameters for neutral stability gives values which are in very close agreement with those suggested by Sutton. However, Sutton does not provide very well founded parameter values for the problem which occurs most of the time in this country, namely, the nonneutral case. The values given in Table 1 will permit making computations for these more frequently occurring cases with which we are concerned.

We may now ask the question: How good are the diffusion calculations obtained by the foregoing method? I will give an indication of this by comparing a series of field trials observations with results calculated for the particular conditions under which the tests were conducted. It should be remembered also that the test conditions were selected to be as nearly ideal as possible, and hence the comparisons represent optimum capabilities for this method.

Table 2 shows several properties of the total dosage field which have been computed: the area covered to some total dosage level, the average dosage (E) over the field, the short time area coverage and the short time average dosage.

TABLE 2: COMPARISON OF OBSERVED AND CALCULATED PROPERTIES
FOR SINGLE MUNITIONS (POINT SOURCE MODEL)

Property	No. of Tests	Range of Obs'd Values	Avg. Ratio Cal'd/Obs'd
Total dosage E(5-max)	16	$5 \times 10^4 - 5 \times 10^8$	1.18
Total dosage E(5-100)	22	$4 \times 10^4 - 7 \times 10^7$	1.00
Total dosage A(100)	16	$7 \times 10^1 - 6 \times 10^4$	0.92
30-second E(5-40)	10	$4 \times 10^4 - 1 \times 10^5$	1.00
30-second E(5-100)	18	$2 \times 10^4 - 7 \times 10^5$	1.53
30-second E(5-max)	8	$2 \times 10^4 - 2 \times 10^6$	2.01
30-second A(5)	10	$1 \times 10^3 - 6 \times 10^3$	0.94
30-second A(40)	10	$3 \times 10^2 - 2 \times 10^3$	1.24
30-second A(100)	18	$7 \times 10^1 - 1 \times 10^3$	1.54

A(i) = Total area covered by at least a dosage of i mg min/m³.
E(i-j) = The dosage-area integral with lower and upper limits of integration of dosages i and j mg min/m³, respectively.

The observed values vary over several orders of magnitude so that a rather wide range of conditions can be checked against the calculations. One indication of the degree of agreement is given by the average ratio of calculated to observed values. As can be seen in Table 2, these approximate unity with a maximum value of about 2 and a minimum value of .92.

Table 3 is a different summary of the data given in Table 2 and shows that for 128 cases the computed value was within a factor of 2 of the observation for 71% to 78% of the occasions tested.

TABLE 3: COMPARISON OF OBSERVED AND CALCULATED PROPERTIES FOR SINGLE MUNITIONS (POINT SOURCE MODEL)

Property	No. of Cases	Correl. Coeff. of Logs	Regression Slope	Avg. Ratio, Cal'd/Obs'd	% Cases With Ratios Within		
					.67-1.5	.50-2	.33-3
A(i)	54	.92	1.02	1.19	52	78	89
E(i-j)	74	.92	.99	1.24	55	71	89

A(i) - area data for all dosage levels, 30-second and total dosage.
E(i-j) - represents all similarly available E-value data.

Another series of experiments, conducted with various elements of a rocket battalion, was used to study applicability of the calculations to an operational scale problem. The dosage field for a single rocket was computed for the meteorological conditions of each experiment, and then built up to the composite pattern by making use of the actual rocket impact distribution in order to predict on-target surprise (30-second) dosages. Total dosage fields were calculated and the results are shown in Table 4.

TABLE 4: COMPARISON OF OBSERVED DOSAGE FIELD PROPERTIES
WITH THOSE CALCULATED FOR MULTIPLE MUNITIONS

Property	No. of Tests	Range of Observations	Avg. Ratio Cal'd/Obs'd
60-minute A(40)	13 ⁽¹⁾	$1 \times 10^4 - 4 \times 10^6$	1.34
60-minute A(100)	13 ⁽¹⁾	$4 \times 10^3 - 2 \times 10^6$	2.05
30-second A(40)	14 ⁽²⁾	$4 \times 10^3 - 4 \times 10^5$	1.37
30-second A(100)	14 ⁽²⁾	$1 \times 10^3 - 3 \times 10^5$	2.09

- (1) Includes: 5 single-launcher tests with 25 rounds per test
2 platoon tests with 150 rounds per test
5 battery tests with 300 rounds per test
1 battalion test with 900 rounds
- (2) Includes: above plus one additional battalion test

The preceding examples involve relatively limited distances of travel, ranging from several hundred yards for small single munitions up to the order of 10-15 miles for the large scale battalion fire. The parameter values, derived from data extending only over several hundred yards, appear to predict the dosage field reasonably well out to these latter distances. It is of interest therefore to examine their possible application to even greater distances. Several series of experiments are available which provide observations over ranges up to 300 miles. These data were obtained by use of particles of fluorescent pigment (ZnCdS) which permit sampling with very high sensitivity, single particles being detectable. The observed results are compared in Table 5 with those predicted for the conditions of the experiments.

TABLE 5: COMPARISON OF OBSERVED AND CALCULATED RISK
DOSAGES FOR LONG DISTANCE TRAVEL OF CLOUDS

Distance (Miles)	No. of Cases	Avg. Ratio Cal'd/Ob'd	Percentage of Cases With Ratios Within		
			.67-1.5	.5-2	.33-3
1	3	.84	--	--	--
1 - 10	13	1.66	38	77	85
10 -100	25	.91	52	72	84
100 - 300	23	.99	22	39	74

The distribution of errors for all cases tested is shown in Table 6.

TABLE 6: SUMMARY OF 296 COMPARISONS

Avg. Ratio Cal'd/Obs'd	Percentage of Cases With Ratios Within		
	.67-1.5	.50-2	.33-3
1.32	52	74	88

Now, in regard to the less ideal cases, what happens if there is heat generated at the source? The mathematics given above don't say anything about that, and yet there are materials which burn upon release, or which are released because of burning. In such a case, one must make additional and more complicated analyses and computations in order to make predictions. However, I wish to point out that an analogous problem involving heat sources at industrial stacks has been extensively treated in the literature so that techniques exist for handling heat sources. There is a converse phenomenon, observed with materials possessing high vapor pressures and latent heats of vaporization: marked cooling is produced through evaporation. This was characteristic of some of the old World War II gases - phosgene, for example. Instead of buoyant rise as with the heat source, there is a gravity sinking and spreading of the cloud which persists until

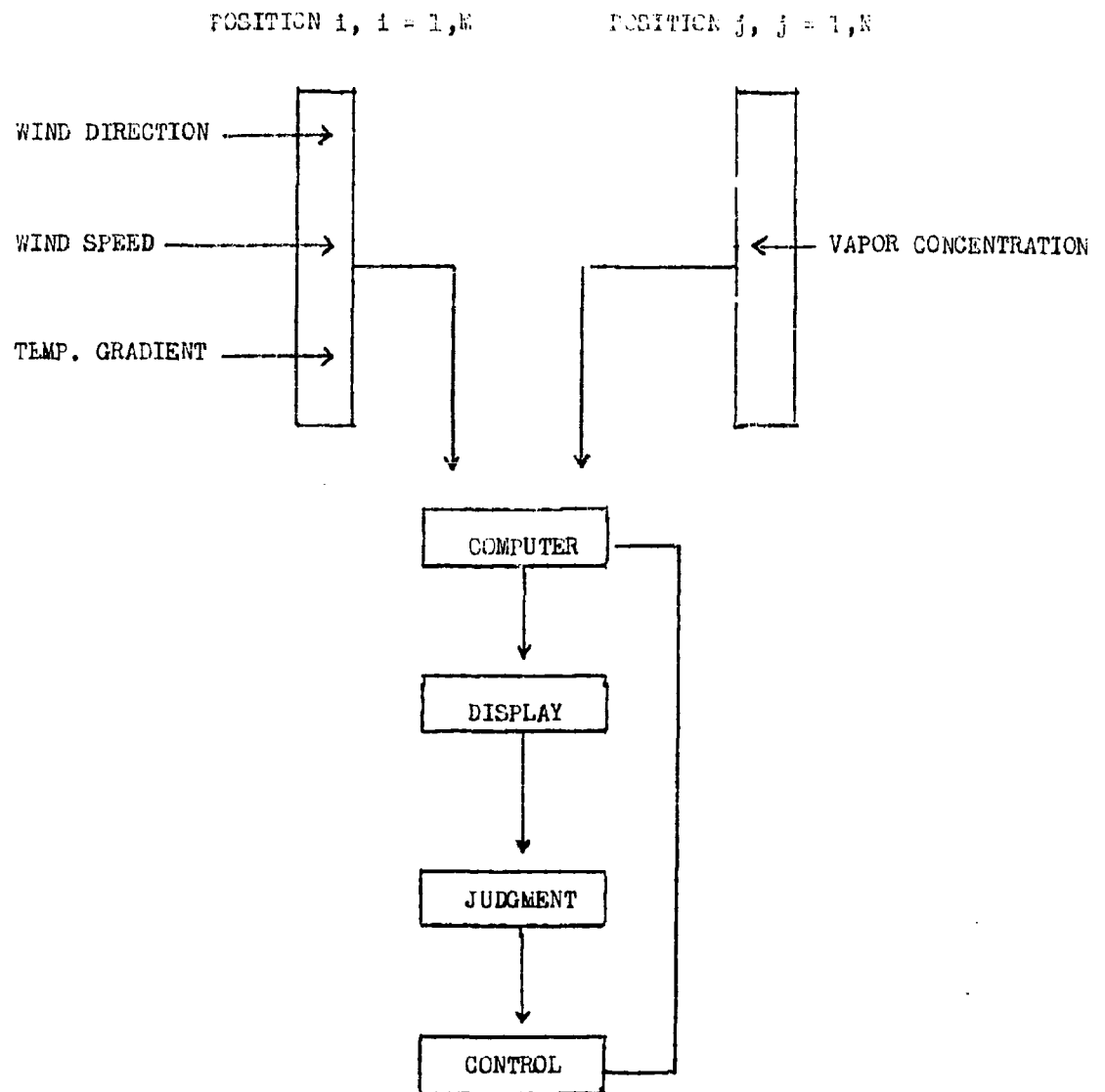


FIGURE 2. Schematic diagram of hazardous agent prediction and warning system.

it warms up to the ambient atmosphere and then begins to behave in the ideal sense treated earlier. Although these problems can be approached by making use of the mathematical techniques developed for stack problems, specific application to your own problems seems not to have been done.

In this final portion of the talk, I would like to speculate somewhat and talk about diffusion instrumentation. The discussion may not be immediately applicable, for technical, economic, and operational reasons, to the diverse problems with which this audience is concerned. However, I will attempt to elicit some concepts which might be reduced to practical utility as a means of minimizing your dependency on an intimate familiarity with meteorological details. The approach I wish to take involves consideration of the broad design features of a system of instrumentation capable of automatically predicting the downwind travel of toxic vapors.

In a very general sense, we would like to make meteorological observations and use them to give some simple, readily understood indication of potential hazards. We would also like to have observations such that, at the instant of release of an agent, or very shortly thereafter, one has available an assessment of the actual hazard with which he is confronted, and can use this information as appropriate in order to activate pre-determined control measures. It is clear, then, that one needs meteorological observations, agent observations and a system which can integrate these observations into a form capable of guiding decisions. This integrating activity would involve the application of diffusion theory which we have already reviewed, and trajectory analysis, i.e., a computation of the actual path to be followed by the cloud. Other special guidelines that may be appropriate to the location would also require consideration. The proposed system is schematized in Figure 2. Measurements of wind direction, wind speed and temperature gradient are made at a set of positions, and vapor concentrations are continuously detected and observed at another set of positions. The volume of data arising from such observations will necessitate automatic information transmission and processing, so this is accordingly a fairly sophisticated system. The information, therefore, feeds into the block labeled as computer. From the computer, information must be fed to some display to facilitate human interpretation, the exercising of judgment and initiation of controls. In certain well defined situations, the computer itself could initiate controls - that is, sound alarms, close traffic gates, etc.

Although this sequence sounds sophisticated, I think it is interesting to note that this is just the sequence of functions which most of you now employ. There is much latitude, however, in regard to the complexity of the equipment or procedures employed to physically implement the blocks in Figure 2. We heard discussions this morning about workers who observed wind direction by shining a spot light on a wind sock. This is

the meteorological observation. We heard people talk about visibly observing the cloud, its height, size and displacement. This is, in effect, an agent sensor. The computer, I presume, was someone's judgment of how the cloud would behave. One can, of course, get ever more sophisticated and in the final analysis choice of system components depends on the particular job to be accomplished. However, let us consider some possibilities. We can certainly advance beyond the wind sock and the spotlight; we can provide graphs, charts or nomograms, for use by an operator to permit rapid computation of various aspects of cloud behavior provided some meteorological and agent information is available. Even more versatility, however, is possible with small digital computers. These are able to perform a variety of computations rapidly and continuously, constantly recycling the always current input information. The machine can compute averages of meteorological quantities for any time period of interest. It can compute stability ratios or employ temperature gradients to control the selection of diffusion parameter values. From appropriate geometric configurations of agent sensors, it is possible to obtain observations which permit the continuous computation of source strength, i.e., the amount of toxic material emitted into the atmosphere as a function of time. The computed value of Q , the source strength, can then be employed by the computer to solve the diffusion equations and provide estimates of downwind concentrations and dosages.

The output from the computer can be fed to a display board, e.g., in the form of a wall map of the area. From multiple point wind observations a modest computer can make trajectory analyses and do a good job of computing the path of the cloud. This will indicate whether critical points in the surrounding geographical area of interest will be affected. The use of the diffusion equation permits estimation of the level of exposure to be experienced by these positions. The results can be fully and continuously indicated on the display.

If, instead of employing agent sensing, an assumption of unit source strength is fed into the computer, the computed dosage will correspond to a pollution potential. Pollution potential is a number which has a magnitude indicating relative potential exposures at the various positions of interest. It also indicates the relative state of the atmosphere in respect to diffusion of the effluent.

There is another extremely interesting and useful application that can be made of agent sensors. This involves what I would call a self-correcting or feedback aspect of the system. You will recall that we spoke of evaluating diffusion parameters from field tests, correlating these with meteorology, and then using observations of meteorological conditions to determine which parameter values to enter into the calculations. And, as we said, this practice is complicated at times by peculiar or nonideal characteristics of the location. For example, at Cape Canaveral there is a special shore line situation produced by the

water-earth boundary. Air moving over the water for long distances becomes equilibrated to a stability condition appropriate to the sea surface temperature. Upon reaching land, it immediately begins to undergo a transition towards equilibration with the new surface. The equations and parameters previously discussed do not apply to such a terrain anomaly. However, in this and possibly other situations where topographic variations complicate cloud behavior, I believe it is possible to employ two or three crosswind agent sampling lines to compute diffusion parameters on the basis of current observations of the diffusion process itself following a release into the atmosphere. This is a direct approach which circumvents complex theoretical problems and consists of using the observed variation in cloud properties with distance to extrapolate to greater distances. The validity of this extrapolation will depend upon the reliability of the mathematical functions which can be fitted to this variation. There are data whereby this approach can be tested, and I would be quite hopeful that it would provide a useful method for handling a difficult problem for which no general solution currently exists.

A further comment may be made in regard to the proposed system. Various workers have undertaken fluorescent particle investigations in order to study diffusion and behavior at particular sites or in near-ideal locations to study the general problem of diffusion. These are fairly costly undertakings. Fluorescent particles are admittedly effective for tracer work, but require special instrumentation and difficult, laborious counting. It would be interesting to compare the cost of such a "one-shot" investigation with the cost of installation of a system as proposed, which could be used to provide similar data in addition to serving a continuing operational function.

As a concluding thought, I would like to emphasize again that, although it appears feasible to automate certain aspects of the pollution problem by introduction of a hazardous agent prediction and warning system, a do-it-yourself approach will not suffice. Much careful competent meteorological study by those qualified in this particular kind of problem, should be enlisted in order to develop procedures and systems designed to serve the needs of each location on an individual basis.

MICROWAVE RADIATION

Colonel John E. Boysen, MC
Chief, Professional Services, Hq AFIC

I am going to discuss microwaves this morning, and if I do nothing else, I want to bring out some of the misconceptions many people have. I think that Colonel Feightner, when he mentioned that he didn't think microwaves belong in the field of radiological health, probably in other words said the same thing -- that so many people seem to have the idea that microwaves are just another type of ionizing radiation, without actually realizing what some of the differences are. So, at the risk of insulting your intelligence, I am going to start from the beginning and point out the electromagnetic spectrum.

SLIDE NO. 1

I am sure that you all recognize this as being, roughly, a chart which shows the wavelength in centimeters. At the far end of the spectrum is cosmic radiation - very high frequency energetic radiation and short wavelengths. As you move toward the other end of the spectrum there will be gamma rays and X-rays, and then visible light which occupies a very small portion of the entire spectrum, followed by infrared radiation. Roughly, microwaves fall in the radiofrequency portion of the spectrum; below that is the broadcast band that we are familiar with in radio.

This slide shows the electrofrequency portion of the electro-magnetic spectrum, the portion of it with which we are dealing. Any number of terms have been given to this portion, and that is the reason why I don't know where this term "microwave" came from. It's not recognized by people in the radio business as anything that can be defined in terms of frequency, but in the communications business these are specific areas which have been given very low frequency. Starting at the bottom, about the 30-kilocycle range, are the frequencies which are below 300 megacycles, that are used for ship-to-shore transmission on the sea. Above that is the broadcast band, which is in the middle of the frequency range at which our standard radios are transmitting in most frequencies. Above that are high frequency and VHF, very high frequency bands that extend up in the vicinity of about 100 megacycles. Finally, there is UHF, ultra high frequency. Some of the television bands are in this area. For instance, Channels 2 to 6 on your television set run from 54 to 88 megacycles, and there is an FM broadcast band that is 88 to 108 megacycles. In the UHF area, some other television bands run from 174 to 890 megacycles. We are more concerned with the band of super-high frequencies, which is getting up into the area where some of the radar equipment operates.

I point this out particularly as it involves one of the common misconceptions. Radar is thought of as being something altogether different; however, you will notice that, mixed up in this frequency, are also diathermy equipment and other types of equipment used in medical research. For instance, diathermy has two bands of 27 and 40 megacycles, and another one of 2450 megacycles which is approximately the same frequency band as S-band Radar, which is just slightly higher at 2600 to 3200 megacycles. We also have the L-band Radar, which is about 1100 megacycles, which approaches closely some of the television channels, whereas the diathermy I spoke of before in the high frequency band and shortwave bands, is of a lower frequency, approaching the broadcast bands. Getting back to Radar again, this is the X-band, which is about 9000 to 9500 megacycles, and is in the one-centimeter wavelength range.

There are only small differences between these different types of equipment. All are designed to produce a radiation which is primarily characterized by its frequency. All of these types of transmitters that are grouped in here, including medical ones, are characteristically continuous wave transmitters. In other words, you turn them on, and if you were to plot this when the power is on it would rise to a certain power, depending upon the nature of the equipment, and continue until you turned it off. This is in contrast to radar, which is a pulsed affair and, if plotted, would show a curve with peaks and intervals between the peaks.

SLIDE NO. 3

I am sure that most of you are fairly well acquainted with the fact that there is another characteristic of radar which makes it important to us, as contrasted to other transmitting types of devices. We want it aimed at something. In other words, we want a very fine beam; therefore, they have designed essentially a parabolic reflector which will do that, or do it fairly well. There are three regions that are important from the standpoint of determining the nature of the power density: the Near Region, or what is also called the Fresnel Region, the Crossover Region, and the Far Region. Most of the time we're concerned with the Far Region. This is the distance which is determined by dividing the square of the diameter of the parabolic reflector by the wavelength. This is a comparatively short distance in most of the radar equipment. In this region, radiation behaves much like light; in other words, according to the Inverse Square Law. But it is a quite different and a complicated matter to determine exactly the radiation received by any object in the Near Zone. If one were to plot this to illustrate this particular point, one would find the plot always varying, depending on the character of the machine. As I said, it's a complicated business and probably not of much practical importance to us here.

SLIDE NO. 4

One other point, the energy in the middle, or the axis, of the beam and extending horizontally, would be by far the greatest. This will depend somewhat on the type of radar equipment and also the power level at which it is being used. But as one proceeds horizontally, one would get a plot which would fall off markedly a short distance from the side and then one would have another rise in the power density and then another one later on. These are spoken of as the primary lobe, which is the one we really want. Of course, the most ideal type of equipment would produce only the primary lobe and none of the secondary or tertiary lobes. The only point I am trying to make is that the major portion of the radiation energy is confined to the very small cone in the middle of the field.

SLIDE NO. 5

One point that I want to get across here is that there are effects of some kind from all portions of the spectrum. In the X-ray region are effects measurable in some form or another, but mostly characterized by ionization. Radiation from the visible spectrum affects the retina of the eye, and it is almost exclusively limited to that. Ultra-violet produces the well-known effect on the skin. Infrared produces heating of the skin and subcutaneous tissues. The primary effects of the radiofrequency portion of the spectrum are thermal.

SLIDE NO. 6

What actually is the coefficient of absorption? How much of the incident radiation in this area does one absorb, depending on its frequency? This is one thing that we don't know a great deal about as yet - something that would help us a good deal if we did know. Somewhere in the area of 200 or 300 megacycles the human body, because of its electrolytic nature, absorbs radiofrequency energy and heats most efficiently.

How does the human being or a biological organism of any kind absorb this energy, and what happens to it? At the present time, the thinking is that there may possibly be three major effects. The first is the ordinary thermal effect; second are certain specific effects; last are electrical effects. A certain amount of evidence has been gathered over the years to prove these concepts, at least to some extent. A good deal of information has been developed concerning the thermal effect, which is direct conversion of electrical energy to heat. It is thought that at least in the region of about 300 megacycles that the cross section of the absorption is about 50%. In other words, about 50% of the energy incident upon a body is absorbed and transformed into heat. This is probably not true at higher frequencies than that, but what this figure may be has never been really worked out. We also have specific thermal effects which occur in the heterogeneous types of material that have low thermal conductivity.

The difference in the thermal conductance of bone, fat and muscle, is significant. You get a different amount as this is absorbed through each of these tissue layers, so there may be different degrees of heating. This is not the only factor involved, because at the same time the tissue is being heated, it is also dissipating the heat via its blood supply. This is a dynamic situation.

There are other electrical effects that have been postulated. One of them has to do with the electrical orientation of the polarized macro- and micro-molecules. One example is that if cells are in a suspension and radiated, they will form a pearl chain. What if this happens, for instance, in the blood stream with the blood cells and you get essentially an effect of coagulation? This hasn't been observed in vitro, but it is a possibility.

In one report that was written by Dr. Silver of the University of California some years ago he said, "Atoms and molecules are complexes of charge, and when placed in an electric field their charge distribution becomes polarized. Some systems, such as many molecules in living tissues, already have charge distributions which are polar; that is, the center of gravity of the negative charge is displaced from that of the positive charge. All membranes have polar structure. In a time varying field, the polarization vibrates and by virtue of interaction between different elements of the molecular system the electrical energy is transformed into heat. This is the dominant phenomenon in what might be termed the low amplitude region. The hazard aspect of radiation in this region is a purely thermal generation of heat. If the intensity of the radiation is so low that the rate of generation of heat can be handled by the distribution processes in the organism, the result is only discomfort. When the intensity of radiation increases, not only does heat generation increase, but another effect comes into play. The enforced distribution of electrical charge under the applied field can be so great that a complete reorganization results. This is what is called the process of field-induced transitions. It is particularly possible in systems comprising unsaturated bonds and relatively free electrons and comprising loose bondings, such as hydrogen bonds, and the interaction is only incidentally associated with the frequency of the wave. Rather, it is one of field effect and could be produced by static fields. The magnetic field vector in the electromagnetic waves generally plays a secondary role in this process. Magnetic forces are considerably smaller in magnitude, but they are not entirely negligible, and in the case of large magnetic field intensities, the force can be built up to a point at which mechanical disruption takes place."

Since that time there has been work - some of it by Colonel Bach at Fort Knox - in which they have gotten electrophoretic pattern changes and increases in antigenic activity, using radiation in the field of from 10 to 40 megacycles. This was found to be true in very specific and narrow regions of the spectrum. This is fairly low in terms of frequency, and below that which would normally be included in microwave studies. There has also been some work which has shown the disruption of OH groups and H groups in molecules with loose bonding of this kind. If this occurs to any extent, of course, you can understand what the effects would be.

There is another concept that might well be clarified. When we talk about microwave radiation, the first thought is about eyes and cataracts. I think this has come about for two reasons: one of them is that eyes are easy to get at, easy to expose, and so more experimental work has been done on eyes than on any other part of an animal. I don't think that this necessarily indicates where the hazard will be in the case of a human being, such as a radar worker being exposed to radar energy. We know more about eyes, it is true, and we also know that an eye, being fairly non-vascular, has poor ability to dissipate any heat that is produced in it. But when one sees a person working around radar equipment, I don't think the eye is the one organ that is going to receive the major portion of the heat or energy absorbed within that tissue. The only exception I can think of - and I haven't seen this happen for years - was when they used to tune some of the old airborne radar sets and would stick their head right in front of the horn to adjust it. But devices have been put in so the technicians don't have to do that any more. With the high-powered equipment we have now in the fixed installations, such exposures are totally unnecessary. However, with that much warning, I'll still tell you something about eyes.

Some of the things that I think are interesting, and this illustrates another point, are some of the different characteristics of various frequencies. One can expose an eye to infrared (this has been done in blast furnace operations) and the infrared damage to the eye is characteristically a cataract that occurs at the anterior cortex of the lens. If one exposes the eye to 10,000 megacycle radar, a cataract beginning at the anterior cortex may occur. At least this is true of rabbits' eyes. However, if it's an L band, S band (3000 or 1000 megacycle radiation) the cataract will be at the posterior cortex. This merely reflects the difference in absorption which is dependent upon frequency. Another thing - and an unfortunate thing, perhaps - with this much radiation aimed just at the eye of a rabbit, a cataract can be produced with sufficient exposure and without any apparent discomfort to the animal whatsoever.

Another rather strange phenomenon that has been reported once that I know of, was by Frye, in which he noticed that the human auditory system can respond to electromagnetic radiation, or at least a portion of it. This response is instantaneous and at low power densities. He speaks of it as being 1/30th of the maximum safe level at the 10-milliwatt figure. He was dealing with 200 and 300 megacycle radiation. Whether the same is true in the L, S and X bands, I don't know. He covered the lower half of the head with radiofrequency absorbent material. With the head covered in that way the individual could tell when the radar equipment was on. He was in

the beam and he could hear it - "A rather high-pitched twang," as he described it. With the top half of the head, including the ears, covered with a radio-sound-absorbent material, then he could not hear it. If they enclosed the antenna in a radome and rotated it (this was so the subject could not see it) when he was swept by the beam he could hear it; this was tested accurately many times. They put a screen between the subject and the antenna so he could not see it, and still he could tell when he was in the beam. This also was repeated many times with the same result. This was the first time I have seen anything of this kind reported. Incidentally, they also checked this further and put sound-attenuating equipment on so that no indication could be had indirectly from just hearing the motors going, and the subject could still tell what direction the beam was coming from.

Some work has also been done, and we often talk about it, where one doesn't necessarily need to feel any heat while in the radar beam and still may get into trouble. This work also, unfortunately perhaps, was done at lower frequency ranges of 20 to 200 megacycles, in which an excellent correlation was found between sensation and the amount of energy to which the person was being exposed. I have nothing to prove it, but we have known for years that this sensation of heat has been noticed by people working around the lower frequency transmitters, who would get out of the field if they were getting too hot, if they knew what was happening. This was probably a good protective mechanism if there was any danger to it at all. I am not so sure that this is true at higher frequencies and at the frequencies of the L, S and X band radar.

There are many other factors which, from a practical standpoint, get mixed up in the possible effects on a human exposed to this radiation. I have discussed the frequency of the wavelength; I have told you that in the lower frequencies you probably would feel heat. Incidentally, when getting into the lower frequencies, a human being gets relatively transparent to the radiation. A lot of these things can be demonstrated in a practical way. If you are working around the antenna of a radio, for instance, it doesn't make much difference to the reception whether you are on one side of or in front of the transmitter. But at a higher frequencies, when you are dealing with television sets for instance, this does make a difference. You are either reflecting or absorbing the energy; your antenna isn't getting it, so the picture and sound are no good. In higher and higher frequencies this is even more true; it more nearly approaches the behavior of light.

In addition to the irradiation cycle rate, the time of exposure, obviously, is another factor which is important. As you know, radar is on for a few micro-seconds and then off for a relatively longer time - perhaps 100 times that - and then on again. But in addition to that - and I think this is of practical importance - in radar installations in which an antenna is sweeping a 360° arc, even though an individual is standing in front of a transmitter, the amount of exposure that he gets is relatively small compared with the total time that the transmitter is on. This is important; we tend to forget that sometimes.

Consideration should also be given to air currents. Some work has been done in which the survival time of experimental animals was increased from 17 minutes to 18½ hours, merely by changing the air currents around the animal up to 16 miles an hour at a temperature of 15°C. All that this means, really, is that if you have a good air current moving past the body which is being exposed, there is a good deal more dissipation of heat. The same is true with the ambient temperature of a room he might be in. This is an expression of the same idea, of course.

Another factor is body weight, the type or the mass that is being exposed. This makes a good deal of difference when comparing experimental animals. In the human being, it is the amount of energy being absorbed which will affect the quantitative absorption and which in turn determines the dissipation of excess heat.

Also, orientation may make a difference. If you have been around these people you probably have heard them talk particularly of two things: the feeling of heat and the tingling in the ear lobes. Another thing, in dealing with energy of these frequencies, your finger may act as an antenna if you put it in the beam. If it is about a quarter of a wavelength along, the absorption of energy will be considerable as compared to what it would be if your whole body were lying in that field. Also, it would make a difference whether you were lying in it lengthwise or whether you were upright in it. Then, there is the difference in the sensitivity of different organs and different tissues. Primarily, this has to do with the vascularity and the ability of the organ to dissipate heat.

The last factor that would have some influence on absorption would be the effect of reflections. This is a two-fold thing, actually. If you go out in the field and measure the intensity of the radiation in what is called a free field, which essentially means measuring in space, it would be one thing; but if you are doing

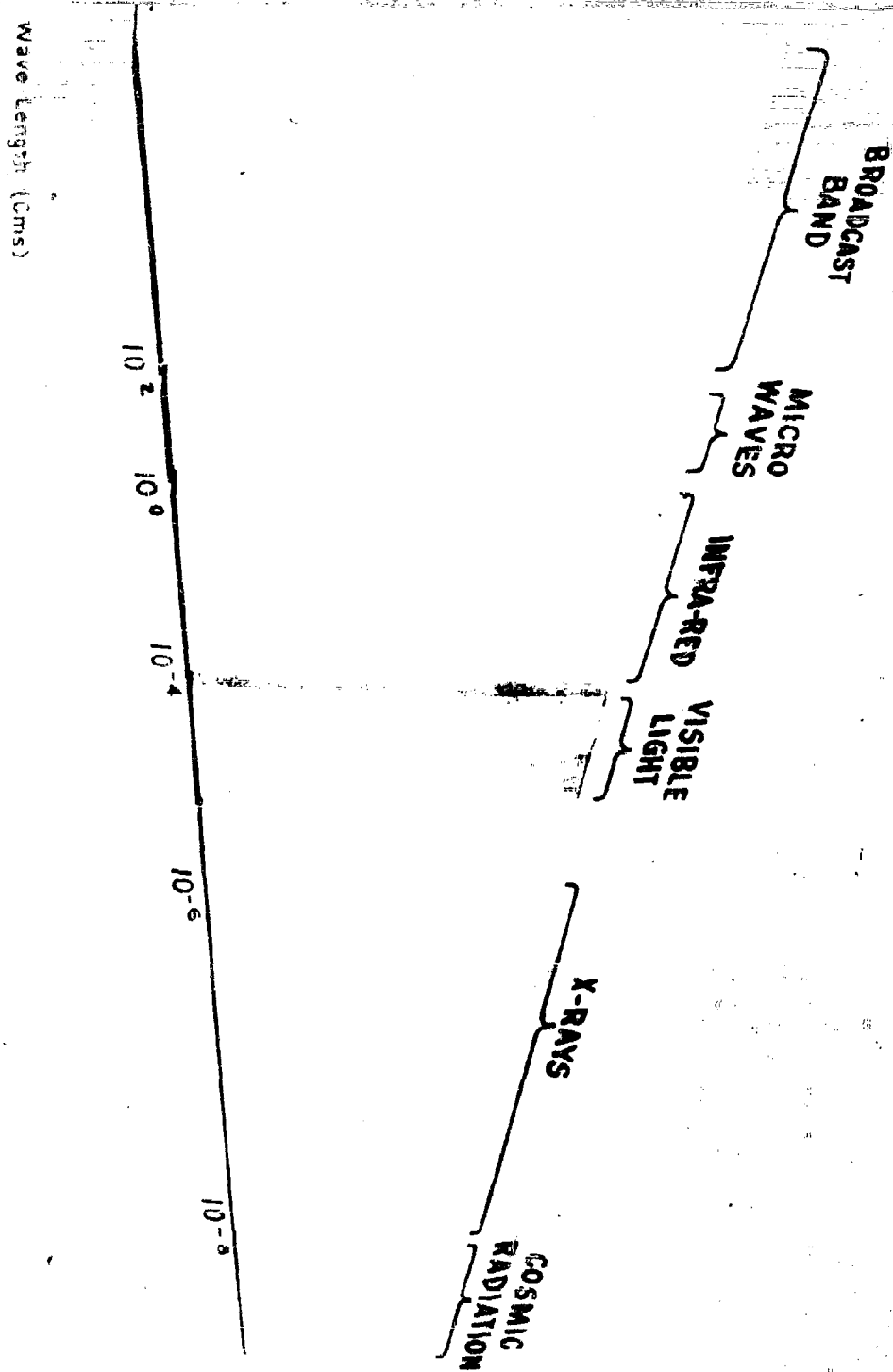
it in a terrain where there may be buildings or other such objects, you may have reflections. In other words, some of the energy is coming directly from the transmitter and some of it is being reflected against the building and back to the point of measurement. A common phenomenon I am sure you will all recognize, is when you are watching television and an aircraft flies over the house and the picture flutters all over the place. This is the result of getting two signals that are not timed exactly the same -- one being reflected from the plane and another one coming direct. So if you are surveying a radar site you may find areas of high intensity which would otherwise be unexplainable.

SLIDE NO. 7

One of the things that has come up frequently is the problem of short term exposures. Some years ago a committee came up with a suggested maximum safe level of exposure of 10 milliwatts per square centimeter. There has been a good deal of argument and discussion, not so much about the validity of it, but as to the problem of application. According to the electronic engineers, this hasn't been too difficult for them to live with, but there has been a good deal of complaint from people who want something that has an indication of time attached to it. I think this has some merit. In ionizing radiation this is done in terms of maximum safe working times, for instance. This is the analogy that is usually brought up. On the other hand, nothing like this is done for a lot of other things in the chemical business, say. Carbon monoxide has a MAC of 100 ppm, but nobody ever says, "Well, if you work in 1000 ppm for 10 minutes this is all right," and follows this by drawing a nice, fancy curve which shows that it is all right to do it that way. On the other hand, I've never heard anybody object to anyone smoking cigarettes when they get about 20,000 ppm CO out of every puff they take. So, getting back to this 10 milliwatts again, I don't know whether it is really necessary to be able to say that an exposure of 10 milliwatts is safe for two minutes or five minutes or whatever it might turn out to be on a theoretical basis. Maybe this ought to stir up a little argument.

I have attempted to describe to you what microwaves are, how they are absorbed, some of the experimental work that has been done, and what the results have been. In closing, I do want to point out at this time that, to the best of my knowledge, I know of no one who has received any injuries directly from exposure to radar. I refer specifically to microwave radiation. We know of injuries from X-ray and ionizing radiation, but not from microwave radiation.

THE ELECTROMAGNETIC SPECTRUM



the ELECTROMAGNETIC SPECTRUM

(RADIO FREQUENCY AND MICROWAVE PORTIONS)

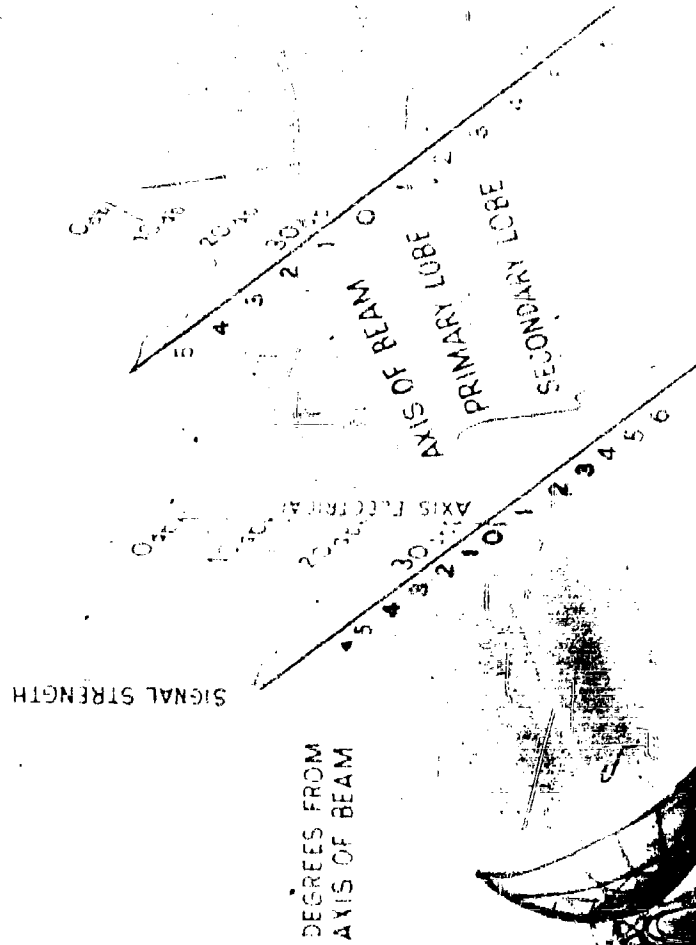
SLIDE NO. 2

DESCRIPTION	VERY LOW FREQ.	LOW FREQ.	MEDIUM FREQ.	HIGH FREQ.	VERY HIGH FREQ.	ULTRA HIGH FREQ.	SUPER HIGH FREQ.	EXTREME LY HIGH FREQ.
ABBR.	VLF	LF	MF	HF	VHF	UHF	SHF	EHF
WAVELENGTH	10^4	10^5	10^4	10^3	10^2	10^1	10^0	10^{-1}
FREQUENCY	30 KC	300 KC	3000 KC	30 MC	300 MC	3000 MC	30000 MC	300000 MC
DATA	27.1 MC	40.68 MC	27.1 MC	40.68 MC	27.1 MC	40.68 MC	27.1 MC	40.68 MC
AM BROADCAST BAND	(535-1605 KC)							
TELEVISION	(CH 1-5 - 54-68 MC)							
FM BROADCAST	(88-108 MC)							
TELEVISION	(CH 7-13 - 174-216 MC)							
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The MICROWAVE BEAM



RELATIVE POWER DB BLOW PEAK GAIN



EFFECTS OF ELECTRO-MAGNETIC RADIATION

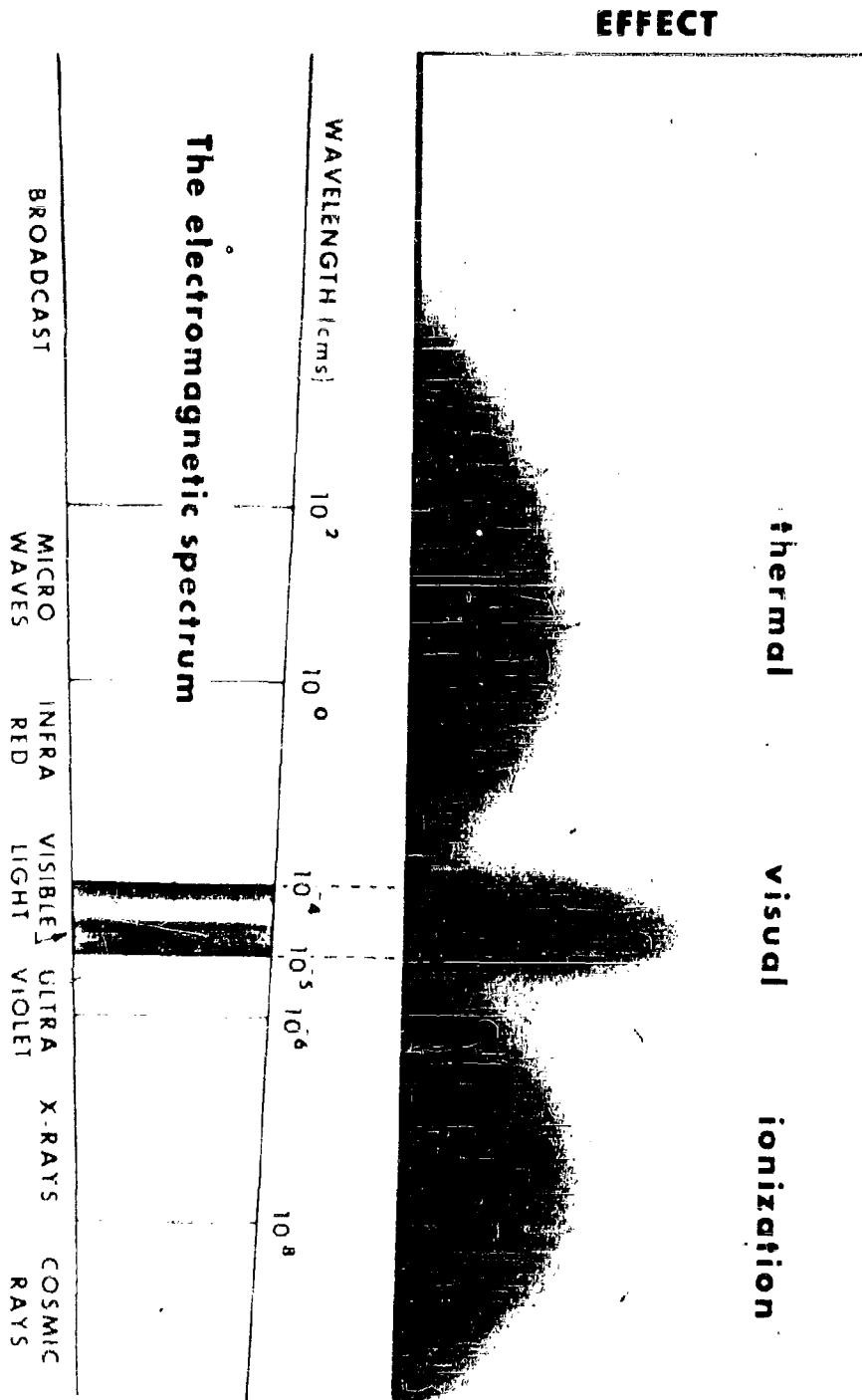


Fig - 1

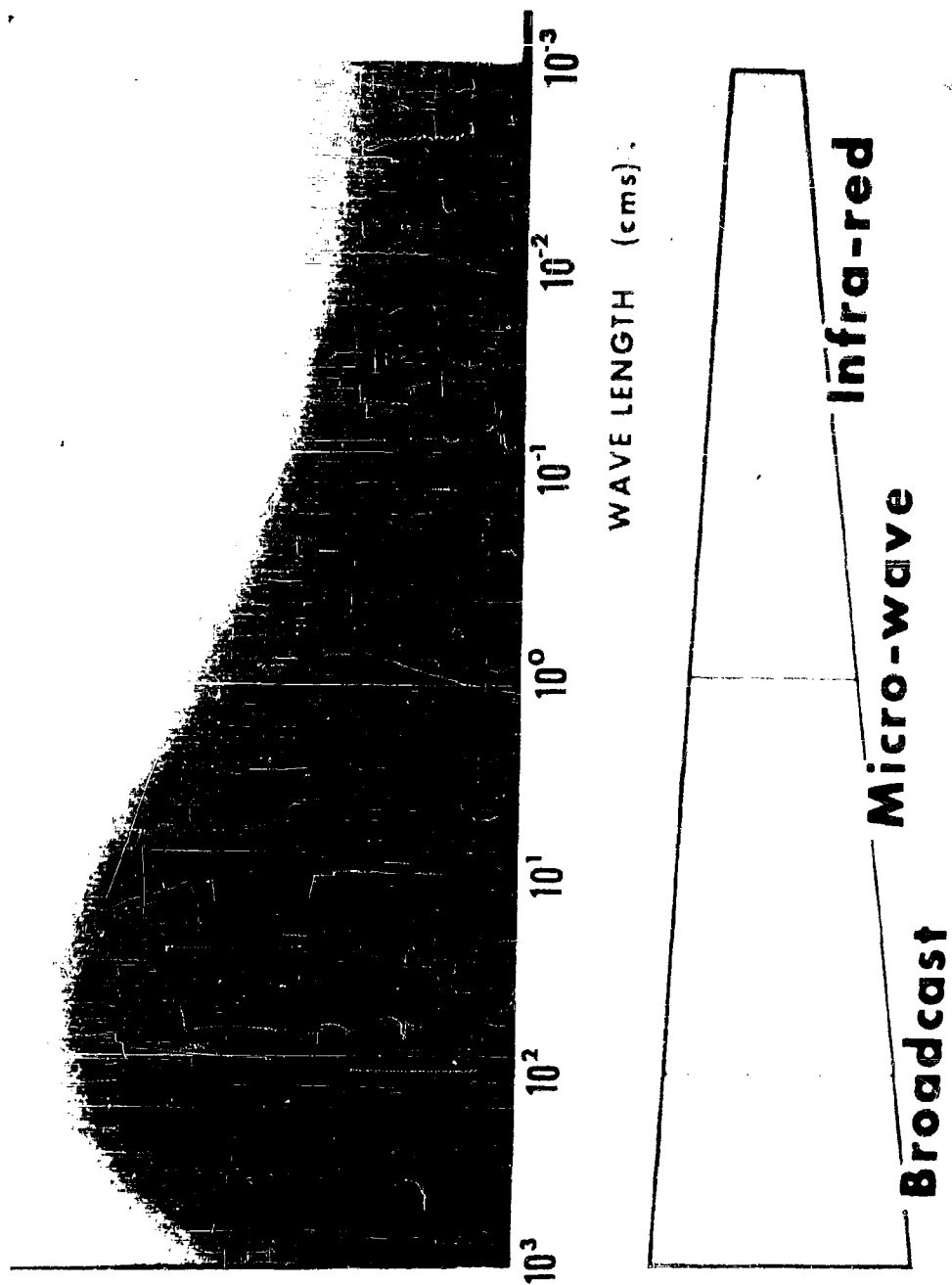
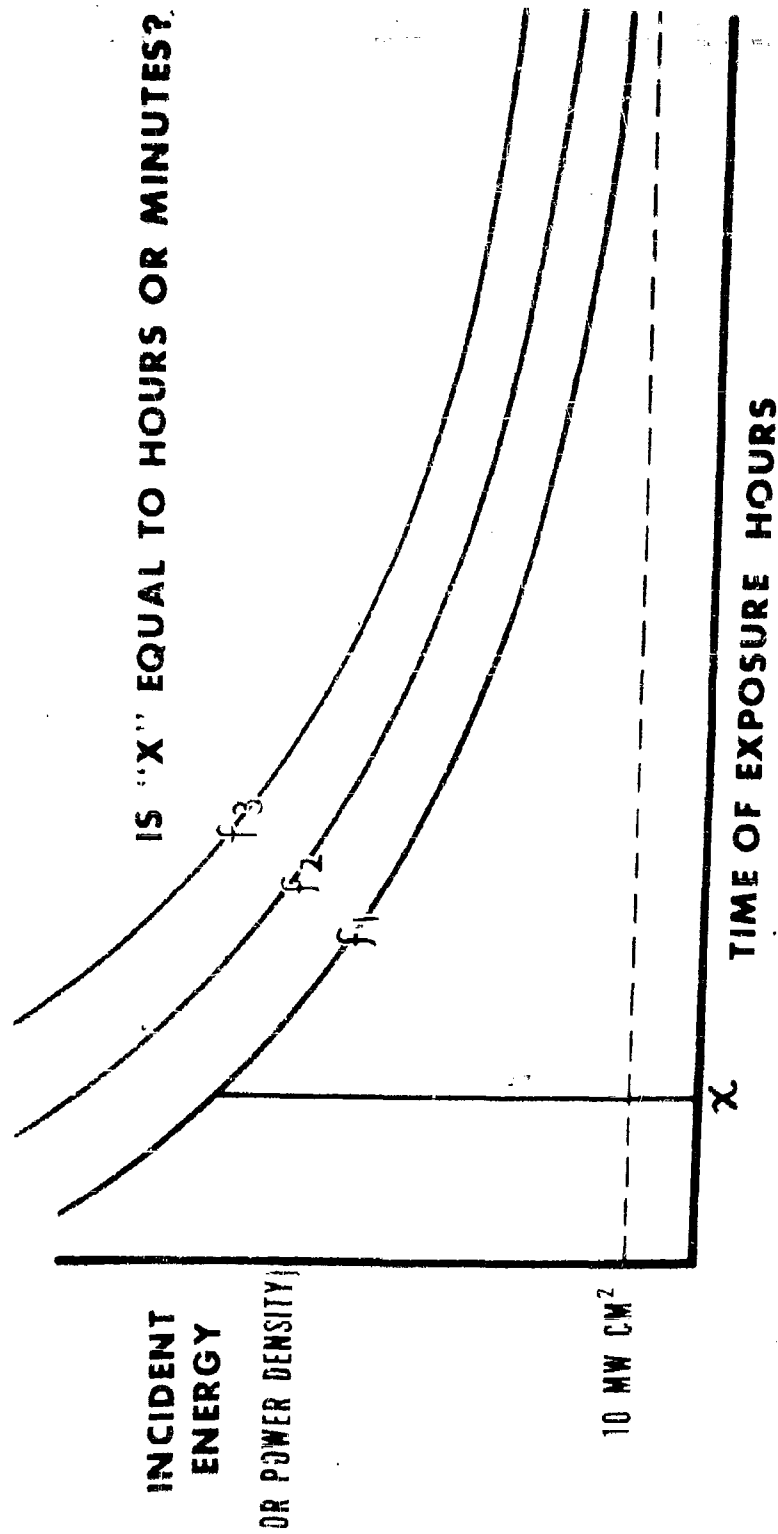


Fig - 2



DOSE-TIME RELATIONSHIP

(For various frequencies)

Fig - 3

X-RADIATION HAZARDS FROM RADAR SETS

Mr. George Clawson
RADC, Griffiss AFB New York

INTRODUCTION

The problem of X-radiation from high power electronic systems has, during the past years, become more and more severe. Not only has the number of such high-power electronic systems sharply increased, but there has also been a major trend toward very high or super power rf output of these systems. Both higher peak output powers and longer pulse lengths are required of such systems. The generation of high-power necessitates, in general, the use of high operating voltages in several active electronic devices, such as the switch and transmitter tubes of the system. Since electrons which have been accelerated by a high voltage will yield X-radiation upon impact on materials, it is quite apparent that such high power tubes will generate considerable X-radiation. This X-ray problem does become more severe both with longer pulse lengths which increase the X-ray exposure lengths and with higher voltages which cause higher X-ray energies.

It is therefore apparent that the problem of X-radiation from electron tubes is constantly becoming more and more dangerous and that a comprehensive study of this subject is imperative.

GENERATION OF X-RADIATION

A brief review of the basic concepts of X-ray production or generation is offered so as to orient the reader to the nature of this particular potential hazard. X-rays are a form of radiant energy like visible light. Their distinguishing feature is the extremely short wavelength--only about 1/100,000 of the wavelength of the visible light or even less. It is this characteristic that is responsible for the X-ray's ability to penetrate materials which absorb or reflect ordinary light.

Any device capable of accelerating electrons to high energies and subsequently causing these energetic electrons to impinge on matter, is a generator of X-radiations. The conventional X-ray tube has the above qualifications. The essential ingredients are a source of electrons, the cathode, a target material, the anode, and a high potential difference between these elements capable of accelerating the electrons to high velocities. Other high-powered electronic tubes such as klystrons, magnetrons, hydrogen thyratrons, etc, possess the basic physical parameters which allow them to act as X-radiation generators.

During the interaction of the energetic electrons with the material of the target, two spectra are produced, superimposed one on the other. One of the spectra is due entirely to the element or elements comprising the target and is similar to the line spectrum characteristic and concomitant with the various incandescent gases after the passage of the light through a spectrometer. This spectrum is termed the characteristic spectrum. The other spectrum is the continuous spectrum and its remarkable feature is that while it extends indefinitely toward the long wave length, it is cut off very sharply at the short wave length end.

The production of the characteristic and continuous X-radiations spectra have a simple explanation. On colliding with the atoms of the anode, or target, some of these electrons, provided they have acquired sufficient energy, will dislodge one of the inner electrons of a target atom, e.g., one of the K electrons. This leaves a vacant space in the K shell, which is immediately filled by an electron from either the L, M, or N shells. The readjustment of the electrons is accompanied by a decrease in the energy of the atom, and an X-ray photon is emitted with energy just equal to this decrease. Since the energy change is perfectly definite for atoms of a given element, precise frequencies for the emitted X-rays can be predicted. This is a line spectrum. Furthermore, it is possible to predict just three lines in the series, corresponding to three possibilities that the vacant space may have been filled by an L, M, or N electron. The lines are referred to as K_{α} , K_{β} , and K_{γ} lines. The K_{α} line is produced by the transition of the L electron to the vacated space in the K shell, the K_{β} line by an M electron, and the K_{γ} line by an N electron.

In addition to the K series, there are other series known as the L, M, and N series, produced by the ejection of electrons from the L, M, and N shells, rather than the K shell. As expected, the electrons in these outer shells, being farther away from the nucleus are not held as firmly as those in the K shell. Consequently, the other series may be excited by more slowly moving electrons, and the photons emitted are of lower energy and longer wave length. Actually, more characteristic lines than the three attributed to each series are evident if theoretical accuracy is prescribed. Modern quantum mechanics has evolved atomic energy level diagrams much more detailed and complete to explain the phenomena. However, the essential features for predicting X-ray line spectra as outlined above remain valid.

As indicated previously in addition to the characteristic spectrum, there is a background of continuous X-radiation from the target of the high voltage device. This is due to the

sudden deceleration of those electrons which do not happen to eject an electron from the target material. A bombarding electron may be brought to rest in a single process, if the electron happens to collide head-on with an atom of the target, or it may make a number of collisions before coming to rest, giving up part of its energy each time. The energy lost at each collision is radiated as an X-ray photon. Therefore, these photons may be of any energy up to a certain maximum; namely, that of an electron which gives up all of its energy in a single collision.

(The wave length characteristics of the continuous spectrum are quite independent of the material of the target but are determined by the voltage applied to the tube.) The intensity of the continuous spectrum, for a given tube current, is dependent both on the target material and on the applied voltage, as well as on the thickness of the target. The positions, i.e., the wave lengths of the lines of the characteristic spectrum are determined solely by the material of the target; their intensity is determined, for a given target material and tube current, by the voltage applied to the tube.

Essentially, these basic physical conditions existing in an ordinary X-ray tube--a beam of electrons traveling a high speed towards an anode, or target (in this case the collector), which is at a very high voltage and the stopping of these rapidly moving electrons--are present in the klystron.

In a klystron two conditions of X-radiation exist - one without rf applied to the tube and the other with rf applied. With the high voltage impressed on the tube and without the rf drive the beam of electrons is more concentrated throughout the body of the tube and less likely to impinge on many random targets giving rise to a multiplicity of X-radiation beams. X-radiation intensity is always found to be greater and more in evidence when the rf drive is impressed, because of two probable reasons. The rf voltage at the output gap adds to the dc beam voltage, giving rise to more intense X-radiation, and the interposition of the rf field spreads the beam of electrons apart as it travels down the body of the tube.

These phenomena manifest themselves more readily when shielding considerations are required in order to make a klystron safe for personnel in its immediate proximity. For example, an experimental klystron has been designed which will give a peak output of 20 Mw. The peak voltage applied was approximately 400 kv, with peak current approximately 250 amp. The average current evolved was approximately 30 ma.

From available data one would predict that a klystron operating at 400 kv and 30 ma average current will produce about 1100 r/hr. To reduce this level to the desired maximum permissible level as allowed by USAF regulations, 2.5 mr/hr for a man working in the vicinity of the tube 40 hrs a week, would require an attenuation factor of about 4.5×10^5 . Using information in available tables, it is found that better than 3 cm of lead is required. Let us assign the operating parameters of a hydrogen thyratron tube 1257 to our discussion. These would be, 38 kv peak voltage, 2000 amp peak current with a 2.5 sec current pulse at a repetition rate of 200 pulses/sec. In order to get an idea of average currents for the production of X-radiation, the duty cycle will be used, resulting in approximately 1 amp average current. While the effective energy of this tube is rather low, 25 kev, the 1 amp current would give rise to rather intense "soft" X-radiation. Again returning to the thyratron, it is noted that the major portion of the X-ray beam emanates in a circle through the screen mesh of the grid-anode region. There may be considerable latitude in X-ray radiation from tube to tube under similar operating conditions due to variations in grid emission. It has been reported that the 1257 has emitted X-radiation intensities up to 10,000 mr/hr at a distance of 1 ft. from the tube. On an average, however, 1200-1500 mr/hr would be a more common radiation intensity.

For the most aggravated conditions 1/16 in. steel paneling would attenuate this radiation down to a fraction of 1 mr/hr. Lead glass 1/4 inch in thickness would attenuate 10,000 mr/hr to a negligible quantity.

Briefly, the high-power klystron operates on the principle of velocity modulation. (It is this velocity modulation that is required for klystron bunching action.) It consists of an electron gun, an rf section made up of a series of resonant cavities with drift tubes interposed, followed by an electron collector. The electron beam generated by the electron gun is focused through the rf section, usually by means of a magnetic field. The electrons are then dissipated in the electron collector.

The analysis is much too simple, and because we are concerned with a special type of X-ray generator, the klystron, the above conclusions must be modified. Conventional tables predict X-ray intensity on the basis of monochromatic radiation. The klystron produces a continuous X-ray spectrum and most of the radiation is less penetrating than those that correspond to the limiting 400 kv energy. The second consideration has to do with the fact that an oscillating klystron has groups of electrons accelerated to voltages approximately twice the beam voltage, or

in this case, 800 kv. X-radiation of greater intensity and greater penetrating powers would therefore be produced. The aforementioned phenomena have made the problem somewhat complex, as the velocity and space distribution of electrons in an oscillating klystron cannot be predicted with any degree of accuracy in the region beyond the third cavity. It follows that at best the calculated thickness of lead can only be used as a guide and the determination of safe radiation protection be accomplished by actual experimentation.

In a tubable klystron, X-radiation output may be increased or decreased by going through the frequency range. Physical location of the X-radiation can be changed by beam focusing and "peaking" with variable parameters.

BIOLOGICAL ASPECTS

From high power X-ray exposures on laboratory cultures there appears evidence that above certain dose rate levels, quick destructive efforts occur. A certain amount of pessimistic speculation as to unfavorable non-linearities or aggravated effects of high exposure rates appears warranted and these parameters should be studied unless one is to forever accept the necessity of extensive shielding. In the case of high power radars aboard certain classes of vehicles, the extra burden of, say a thousand pounds of lead, may be quite intolerable.

Laboratory experimentation can investigate for evidence of pathological events after exposures to dosages representative of radar equipment. Simultaneously, the general effect of ionized body material should be studied. Some similarities to r-f radiation are noteworthy: The primary or immediately obvious result of r-f radiation is to produce tissue heating. Recent studies, not directly concerned with biological effects, show that physical reorientation of molecules and particles occur in r-f fields, the specific positioning being a function of frequency, power level, and pulse duty cycle. There is every justification in this case for the current effort to determine whether "reoriented" blood corpuscles and other body electrolyte materials are going to behave in an exactly normal way.

Similarly, in the case of pulsed ionizing radiation, also involving radiation of high amplitude but of low integrated value, there may be electro-chemical or physical effects potentially damaging to living organisms, and these effects are not yet understood. If safety to personnel is to be combined with equipment economy and simplicity, a determination of the effects of residual or inevitable X-radiation from peak power radar equipment must be determined.

X-RAY DETECTION

GM tubes, proportional counters, and ionization chambers share in common the principle of ionization of a gaseous medium and subsequent electrical detection of the charge produced. Of these, GM tubes give the largest pulse output (of the order of volts across 100's of K), whereas proportional counters give only millivolts, and ion chambers give fractions of a millivolt. In any case, it appears doubtful that even several volts output would be sufficient to overcome likely electrical interference, and so ionization type detectors, operated in the pulse mode, are probably unacceptable, on this ground alone. In addition, however, the output of GM tubes is not directly indicative of biological hazard, although proportional counters may be used to measure the spectrum (at low energies) from which the biological hazard may be evaluated, but both devices are subject to coincidence loss (especially likely in connection with pulsed electrical devices.) Ion chambers, when operated in the current mode, are the most directly indicative of biological hazard, but require either a very high input impedance amplifier or a very high gain amplifier (at low input impedance), again rendering them subject to electrical interference. While GM tubes and proportional counters can be operated in the current mode, with relatively high outputs, such operation does not obviate the question of coincidence loss. Finally, all three devices are subject to spurious ionization by high intensity or high frequency electromagnetic radiation, and in general, any sufficient shielding against the latter is likely to exclude an undue portion of low energy X-radiation.

SCINTILLATION DETECTORS

Scintillation detectors may be operated in the current or the pulse mode. If the pulse mode is desired (which it might be for energy distribution measurements), a high gain photo-multiplier tube is required, and this device is notably subject to interference by even the earth's magnetic field, let alone high intensity RF. In addition, for spectroscopic measurements, the photo-multiplier must be held in close contact with the scintillator, thereby preventing its being operated at a location remote from the source of radiation. Operation in the current mode, however, does allow use of a remote location and in addition, if the original intensity is high enough, may permit the use of just a photocell rather than photo-multiplier. Such operation also obviates the question of coincidence-loss which would otherwise be present. As to the scintillator itself, it is to be noted that NaI is quite temperature dependent and also subject to thermal shock, as well as being far from body-equivalent in its response. Anthracene, stilbene, or a plastic

scintillator would be preferable in all of these respects, but different thicknesses would have to be used for different ranges of X-ray energy in order to maintain body equivalence.

CONCLUSIONS

In conclusion, let me say that for some time RADC has been aware of, and has kept abreast of, the problem. As new equipment is developed, continuous surveys are made to determine the extent of any hazardous conditions that may exist. New electron tubes of the high-power variety are investigated to determine possible X-radiation parameters, and quasi-membership is maintained in the tube manufacturers' Electronic Industry Association to keep abreast of, and offer consultation to, the state of the art. As a result of these activities, RADC has generated Spec. MIL-R-9673C, entitled "X-Radiation Hazards" and has maintained constant surveillance in the field to facilitate revisions of specifications as they are required.

RADC at this time has an OSR requesting development of an X-radiation monitor and alarm system. Programming on this task has been accomplished, but due to the low priority which has been assigned, funding is almost non-existent. The ME/118 Radiacmeter has been assigned to the same task for further development and service test, so it appears as if it also will fall by the wayside.

There is some light in this darkness, however; under a study contract sponsored by RADC, a theoretical analysis of Pulsed X-radiation is being performed. It is our hope that from this study we may realize some empirical formula and possibly some design criteria which will allow us to better cope with this adversity.

In the interim, it is felt that a firm and mandatory educational program be established to instill in those persons directly associated with X-ray-producing electronic devices, a better understanding of the ramifications involved.

THE HEALTH PHYSICS PROGRAM IN THE USAF

Lt. Col. David I. Livermore, MC
Office of the Surgeon General
Washington, D.C.

I welcome this opportunity to discuss the subject of Health Physics with this group of engineers because, as Colonel Feightner alluded to this area as a shred-out from Industrial Hygiene, many of these programs are group efforts. I don't really like the word "team" any more. It has had too much of a political connotation over the years, and when we pick up these cliches they sometimes tend to lose their meaning, so I prefer to refer to this now as a "group effort", because that is just what it is.

There is just too much scientific knowledge extant these days for any one person to grasp the whole field. Consequently, in the conduct of our operations, we of necessity must keep talking to each other so that we know what the other person is thinking, what his role here is, and how we bear our relationship to him in his particular function.

The term "Health Physics" is probably not as precise and specific a term as we are tempted to believe. This term had its birth during the Manhattan Project during World War II. I presume that it arose simply from the fact that more physicists knew more about this subject of radiation and its hazards than did the medical profession, so instead of becoming medical in nature it became health in nature and tied up with the mathematicians and physicists. It has taken quite a few years since that time for us to grasp the concept of radiation hazards to health and put them in their proper perspective in the various disciplines in the medical and allied professions.

I shall not dwell in any detail upon the specific area of interest within the Health Physics Program, or Radiological Health Hazards Program within the Air Force under the purview of the Medical Service. I think it rather significant to note that nine of the presentations in this symposium are very directly related to the Health Physics Program. This, I am quite sure we all understand, is not a meeting of Health Physicists. It is a meeting of Sanitary and Industrial Hygiene Engineers. The more extensively trained health physicist is a specialist in his own field, and he cannot cover the entire field of Health Physics all by himself any more than the field of medicine can be covered in all of its aspects by any one particular specialty in the field of medicine.

Probably our most common source of ionizing radiation which can produce damage to human beings is that which we deliberately apply in medicine. This is the source of ionizing radiation, our X-ray machines, which we have at practically every Air Force installation all over the world. We generate an awful lot of ionizing radiation with these things, and in general, through adequate education and training and good discipline within our own medical activities, we maintain adequate control.

We have been quite successful in administering our radiation protection program throughout the Air Force Medical Service within our own particular bailiwick, avoiding not only excessive exposures to the patient by adequate consideration by the clinician of what X-ray procedures need to be done, but through a process of long, difficult education we have come to the point of protecting our own medical personnel who work around this equipment. Just a week or so back I had a very interesting discussion with a radiologist in Dallas whose father was a pioneer in Radiology. When he had gotten his first X-ray machine, he had a little boy cranking the generator. The little fellow was well fed and eager, and early in the day would get up around thirty or forty kilovolts on this thing. During the course of his lifetime, the old man was estimated to have a total body exposure of 3500 roentgens. He did have a little dermatitis on his hands, but he died at the age of 85 without malignancy, without leukemia.

If we looked at this great series of one, we would discover that ionizing radiation is no problem at all, but we know statistically that this is not the case. In our own medical organizations we are coming to another area with increasing rapidity, another source of ionizing radiation, and that is the medical radioisotopes. At the present time we are establishing our isotope centers; we have about nine of them programmed around the world right now so far as the diagnostic aspects of isotopology are concerned. We deal with levels that are almost insignificant, so far as health hazards are concerned. None the less, we have to keep good, constant surveillance on this activity to insure that the isotopes are appropriately handled. This falls into the area of health physics in the management of acquisition, licensing, storage, and disposal. The clinician himself who is using these in diagnosis is responsible primarily, of course, for the safety and welfare of the patients.

When we get into areas of the therapeutic use of radioisotopes, we get into radiation hazards of a different order of magnitude - enough so that it is necessary at times to shield the staff working around a patient from the radiation emanating from these sources that have been implanted.

One area, I'm sure, that many of us recognize that has been inadequately controlled in the past, is that of Radium. Radium, like X-ray machines, existed before the chain reaction, and consequently when the law was passed establishing the Atomic Energy Commission, with its control over the dissemination of radioisotopes, radium was expressly excluded, for the simple reason that it existed before, and as somebody said many, many years ago and quite fallaciously I'm afraid, "The medical profession knew how to handle radium, and therefore there was no problem at all." Of course, this fellow was totally unaware of the fact that there have been cases of a nurse who has a desk right across the wall from a completely inadequate PIG containing radium and sits there month in and month out getting a fair exposure. When her white count gets down far enough, she becomes a problem until somebody finally finds out what is wrong.

This is becoming less of a problem, but still it is an area to which we must pay considerable attention. We are studying the problem right now of putting radium into the same category as the rest of the radioisotopes whether they are naturally occurring or artificially developed. Outside of the medical area where we are utilizing ionizing radiation, we have an extensive and expanding industrial base of ionizing radiation. There are many areas in the Air Force today where industrial X-rays are used in the examination of materiel. Radioisotopes are rather extensively used in everything from luminous dials to marking and measuring devices, and some of these sources achieve considerable magnitude. We deal with multicurie sources, and these present problems that are certainly of real consequence, so far as the Health Physicists are concerned.

The area of research and development concerning radiation is an extensive and an expanding one in the Air Force, and after all, the Air Force has a monstrous research and development program covering an extremely wide spectrum of interest and disciplines. Radioisotopes in our research programs are used for purposes of measurement, and in many instances become the specific subject of the research and development. For one example, something which is becoming pretty close to the Air Force heart these days is the transit SNAP device. The SNAP device that went off into orbit from the Air Force real estate happened to be owned by the Atomic Energy Commission, but their interest extended no further than the launching pad, and if anything happened, it was the Air Force's responsibility to manage the health physics aspect of the break-up of this isotope source. And here we are dealing with Plutonium. Plutonium we know a lot about, and with appropriate management we know that we can handle the problem and contain the hazards. However, we are usually thinking of Plutonium 239 with a half-life of 24,000 years. This SNAP device is of Plutonium 238

with a half-life of about 90 years. The specific activity of this material differs by an order of magnitude, and consequently, the health hazards arising from this are increased. To go on rather quickly, the power reactors are not only on the threshold, they are practically on the scene right now, and the Health Physics management of the day-to-day operation of these reactors is a very real Health Physics responsibility and activity.

I just left the Nevada test site last night to come here. We're back in the testing business again. We are producing radio-activity in monstrous quantities; we're doing it underground right now, so it's being contained. However, we have to insure that for a long, long time to come, no individual goes into that area and starts to drill a hole down into that stuff, not knowing that it's there. Long time control of radioactive sources is a very real responsibility. The Atomic Energy Commission is retaining its own responsibility in taking care of waste disposal rather than passing this off to the State level. I'll come back to the discussion of the State level of radioisotope control in a moment.

We have not only our Staff and Operational Health Physics personnel, either in the form of completely trained Health Physicists or in personnel trained primarily in other disciplines with an overlay of Health Physics, to handle varying levels of responsibility. In support of this we have, of course, our centralized laboratory facilities at Wright-Patterson, under Captain Markarian, to provide all of the necessary laboratory procedures on environmental samples, gas samples, body fluids, specimens, etc. We have the benefit of quality by this centralization because this area of activity and laboratory analysis of radioactive materials is a very tricky one, and the number of people competent to do this at the level of quality which the Air Force says we must require, is in very short supply. By cross-examination between the other national laboratories and our own laboratory, we have maintained the standards so that we have developed a high degree of respect outside the Air Force both in the DOD and in industrial and university areas, for the quality of work that this particular laboratory is doing.

Of course this laboratory also is the central point for the processing of film badges. Although the film badge is not the end item so far as measurement of radiation exposure is concerned, it is one of the most important devices. One of the primary elements of an education in Health Physics is to recognize the deficiencies in our detection and measurement systems of dosimetry. For efficiency in record keeping, we have all of our film badge data located in one place. At the present time an automatic processing system is being acquired, and already part of the data processing equipment is in place. By the end of the year we

should be on a completely automatic IBM system for all radiation exposure data for our Air Force personnel world-wide.

We are working in very close coordination with the Army and the Navy on this so that ultimately we expect practically an automatic cross-servicing, because we find a lot of places where Army or Navy personnel are being film badged by the Air Force and vice versa, and if this system is fully developed, then we will have an automatic feeding-in so that each individual's complete record will be available at the punch of a key in one central spot.

None of the rest of the world has achieved anything like this degree of competence in maintaining records of radiation exposures. The Air Force, then, can be real proud of this. We are being looked at with envy by many of the national laboratories and the industries for being able to come up with a system by which radiation exposures throughout a lifetime can be maintained in this fashion.

We have certain areas of interest coming up in the future for which the Medical Services have a fair degree of responsibility. It is the policy of the Atomic Energy Commission to turn over the licensing and inspection for use of radioisotopes to State governments as soon as possible. For this purpose the AEC has established the State Services Division which administers training programs for state organizations so that they can develop the competence to take over this function from the AEC. Very early in the game we got most interested in this whole business because we do not wish to run into the problem of trying to deal with fifty-one different independent agencies - fifty states and the District of Columbia. Already we've been flooded by requests from various of these governments for listings of our radioactive or radiation-producing sources within their geographic territories. We have had a DOD General Council's decision on this. We are nice to these people; we are interested in cooperating with them. But we just don't have the staff to go out and count every dental X-ray machine on every Air Force Base and go back and tell them where it is.

With the turning over of licensing and inspection responsibility to the states, and incidentally the state of Kentucky has already signed its agreement, I thought that the Air Force had provided them with their top corps of physicists, but I discovered that they did not get them. They got outbid, so that our lieutenant got a \$13,000.00 job somewhere else instead. The Air Force is actively engaged in its own plans and programs to take over its own inspections and licensing responsibilities as soon as the Atomic Energy Commission is ready to get rid of it. They would like to get rid of it as soon as possible because they figure that the

Air Force right now have more competence to do isotope or radiation inspection activities on Air Force installations than they do, because they feel that their inspectors can't find them all. Perhaps we can't either, but we at least have a much better chance than they do, so they are very anxious for us to take this over. We've already made a verbal agreement that our Air Force personnel who will do the inspecting will spend an adequate period of time with the AEC inspectors in the field developing the techniques of doing these field inspections, to insure appropriate handling and management of isotopic sources. I think here you probably can just feel the finger already.

This level of activity is something that can be very easily handled by an Industrial Hygiene Engineer with a reasonable overlay of training in health physics, and that is what the so-called ten-weeks course which has been put on at Oak Ridge a few times has been directed toward training inspectors for State governments. We have had less than perfect results in trying to get Air Force personnel into the courses because we are not a State Government. I hope that in the future that we can get the established specific course for our own purposes so that this competence can be improved.

Now I would like to touch on what I feel is our primary and most fundamental requirement. The Air Force is designed to be trained, ready and competent to fight a war on a no-notice basis. If such a war should start with the use of nuclear weapons, then the radiation environment becomes an overwhelming and overriding concern. None the less, it is our responsibility to insure that the Air Force can continue to maintain its competence in the presence of, and in spite of, such radiation in the environment. The people best qualified to determine what this competence can be, are those in the Medical Service who know about the effects of ionizing radiation and know how to protect against it and who have developed a sufficient concept of what is going on, to realize that there is a difference between radiation hazards in a peacetime industrial situation and those in the operating environment of a war. We are concerned only in maintaining the active immediate competence of a combat force during wartime. It would be very, very nice to insure that a man did not die five years younger, but I think that this is probably a less important problem when the possibilities of living for another 24 hours may be the major consideration. We have, therefore, prime concern in coordinating with the proper people to insure that our shelter activities are appropriate. This has become a decent word, finally, after all these years. Radiation fallout shelters are now popular. It used to be a real dirty word at a time when evacuation was wonderful. I think things have gotten into a much better perspective. There is a much broader

understanding; but at base level, we find that there is a profound void so far as a real, specific understanding of the problems is concerned.

All too frequently we in the Medical Service stand around and wait for other people to come around and ask us for our opinions. There are certain areas where we must not allow ourselves this pleasure and privilege, for the simple reason that there are certain problems that we know about but which they don't know exist. They are not going to ask for an answer to a question unless they know what the question is. Again it goes back to the old business of communication. We have got to talk to people so they will talk to us.

About a year and a half ago there was a considerable amount of friction insofar as the Safety programs were concerned, with the sudden advent of this great, big safety organization that just sprang full grown into being. It took a long time of just communicating, talking to these people until they finally could get the understanding of the interrelationships of the safety program with the Medical Service program. I was very pleased at the Safety Congress last week to discover that these people are fully aware of this. I couldn't see any areas in which there was a lack of concept that safety and the medical programs were very closely interdigitated and that the safety people should not, could not, assume medical functions, because they lacked the competence. At least now they recognize the fact that there are certain areas of medical interest, and I think that Colonel Smith is very profoundly responsible for this being an engineer in the Medical Service, living with and talking to the people in Nuclear Safety, so that they will recognize clearly the divisions of responsibility and certain areas in which Medical Service must accept and assume its responsibility and functions.

Now a word about the personnel and training situation. We are actively engaged of course at all times in recruiting qualified people for advanced training. A Sanitary Industrial Hygiene Engineer who takes a Master's Degree course in Health Physics is a jewel to behold. The non-military groups who use health physicists envy us considerably when they see the number of engineers who have a master's degree in Health Physics. This is a step above that which is available to them. Of course they are not averse to piracy, and we have lost some of our real fine competents. I feel at times that Colonel Al Meyer probably expressed it adequately when he said, "I think the only answer to our problem is just to train so damn many of them we saturate the market." The trouble is that the market keeps expanding and when you consider fifty-one agencies all wanting well-trained people, so that they can handle their own licensing and regulations organizations, we can't train them that fast for them.

The ten-weeks course gives us competence at a different level, and I think this limited amount of training is appropriate only if it is appropriately applied. We can't all be fully qualified specialists in everything, but if the individual is a well-enough educated individual so that he can recognize his limitations, it ought to help. Unfortunately, however, Alexander Pope was just too correct when he said, "A little learning is a dangerous thing. Drink deep or taste not the Pierian Spring. Shallow drafts intoxicate the brain, and drinking deeply sobers us again."

At the higher levels of Organization Commands in the Air Force we have a very real responsibility so far as the personnel in this field are concerned. Good utilization of these people, proper utilization, is a responsibility which probably lies most directly at the Major Command level to insure appropriate assignment. We cannot economically or financially compete either with other governmental agencies or with civilian industries, so far as the salaries are concerned. So I think, again, our only hope for maintaining our people is appropriate motivation and utilization and this is the responsibility that falls primarily on those of us who are on the senior level.

MEDICAL SERVICE FUNCTIONS
IN PEACETIME NUCLEAR ACCIDENTS AND DISASTER CONTROL

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I realize that, because of the heavy attendance of SAC engineers, much of what I have to say this morning will be old-hat to many of you. However, I trust that those of you unfamiliar with this subject will become at least minimally stimulated and informed and, in addition, I hope that the SAC personnel are not so optimistic that they would not find this review of some benefit.

Whether we confine ourselves to those medical service functions associated with peacetime nuclear weapons accidents, or with any manner of disaster, the various procedures and actions could be as numerous as there are groups that might be involved. The things I wish to briefly discuss represent the approach and method utilized by the Strategic Air Command. Fortunately, this system of response and responsibility is not merely thoughts that have been inscribed on paper, but rather it is at least one set of proven and experienced guidelines. While SAC is certainly not the only agency having been involved with nuclear incidents, it has suffered to date the majority of these situations under discussion.

While our organization is primarily prepared to deal with weapon incidents, it is at the same time motivated and equipped to participate in any other type of nuclear accident, or in any manner of non-nuclear disaster. Such should be the case with any disaster control team, going by that name or another, associated with any military or non-military organization.

The types of weapon accidents, exclusive of the factors relative to the carrying vehicle, and whether occurring in association with flight or not, include fire or high explosive detonation, or both, with virtually no effect on nuclear components; fire or high explosive detonation, or both, with burning or dissipation of weapon components; toxic thermal decomposition of other chemicals or materials associated with the weapons, resulting from either of the first two types; and a very low yield nuclear explosion. This last possibility, because of the nature of weapons design, is considered to be a negligible hazard; the principal hazard would result from detonation of high explosive weapon components rather than from fission.

These accidents may occur anywhere and any time along the chain of movement from the point of manufacture to the point of storage or utilization. While SAC could be involved at any link along this chain, our most common problems have centered at the base level, and primarily in association with aircraft misadventures.

A variety of interrelated problems arise as a result of a nuclear weapons incident. The first consideration obviously is the saving of life and minimizing injury to personnel involved. If the weapon should not directly be affected, measures must be taken to prevent damage to it or to preclude its becoming a hazard by one of the ways mentioned earlier. Very important, but all too frequently not considered, is the fact that off-base civilian personnel and property or on-base military and civilian personnel and property may be involved, raising the question of possible claims for damage. Invariably, apprehension and concern among both military and civilian personnel becomes evident, and a serious problem of press and public relations can result. Therefore, response to such an incident involves medical, legal, explosive ordnance, engineering, security, and operational personnel, all of whom should be properly trained, adequately equipped and operating as a team under competent direction.

Before proceeding to a description of individual responsibilities, and actions, it is well to review some of the hazards associated with nuclear weapon incidents. While our weapons are designed such that there is little likelihood of a nuclear explosion in accident situations, the remote possibility of a small, low order nuclear detonation should not be entirely discounted, and beta-gamma monitoring for the possible presence of fission products is necessary. Such monitoring would also detect certain weapon components that normally emit a small amount of gamma radiation. In the event of an improbable low-order nuclear detonation, high energy gamma radiation and neutrons, as well as beta-gamma radiation from fission products, must be respected.

In instances where there is no nuclear yield, there may be contamination by unfissioned nuclear material, notably plutonium and uranium. These may exist as various sized fragments, including fine particulates, should the components have been burned or fumed. Depending on the nature of the incident, varying problems of contamination may be created.

Dissemination of plutonium or uranium over the incident area as a result of fire, high explosive detonation, or possibly other means, is therefore the prime radiological hazard. Should these components ignite, burn or fume, these alpha emitters may be finely deposited on nearby and perhaps more remote surfaces.

The hazard from plutonium far outweighs that from uranium, and protective measures against plutonium will provide sufficient protection as far as uranium is concerned. As is known, alpha emitting materials do not constitute an immediate or external hazard and a so contaminated area may at least theoretically be occupied continuously provided certain basic procedures are observed. These materials become a primary health hazard only when and if they enter the body. As can be surmised, the detonation or ignition of these nuclear components

results in a radiologically contaminated cloud which is thence moved under the influence of existing meteorology. While this cloud no doubt is ominous, only under extremely rare conditions would personnel caught in its path sustain a body-burden greater than the lifetime permissible concentration. Admittedly, it is good practice to avoid entry into or prolonged exposure in such a cloud; however, there should be no hesitation on the part of emergency response personnel to so expose themselves, even without respiratory protection, if the situation so warrants.

As implied earlier, nuclear weapons are associated with varying quantities of high explosives. This material may detonate in the usual manner, producing blast and thermal effects that are relatively common knowledge. Not only are high explosives dangerous from the viewpoint of detonation, but should they burn, the smoke and fumes may readily contain highly toxic materials. In addition, should this material be broken up and scattered without detonation or burning, an area operational hazard is created since these fragments frequently become shock or impact sensitive and may explode even if slightly disturbed. Some explosives may even melt and flow without burning, then resolidify; these residues, too, are highly sensitive to shock and impact. In addition, the detonators themselves may continue to be shock sensitive, all of these factors then requiring care and caution during response and recovery efforts. Although not associated with the weapon itself, burning fuel from aircraft or carrying vehicles, or fires resulting from weapon detonation, may be a casualty producing parameter.

As should be known to most of you, AF Regulation 355-7 requires each Air Force base to develop the capability to cope with nuclear weapons incidents. In consonance, a disaster control team has been established both at Headquarters SAC, each numbered air force or comparable headquarters, and at each base. These teams consist of: a medical officer trained or capable in nuclear medicine; a sanitary and industrial hygiene engineer of the medical service experienced in health physics, hazardous toxic chemical detection, and environmental surveys; a munitions specialist familiar with weapon design; a munitions specialist qualified in explosive ordnance disposal; an operations analyst qualified in weapon phenomenology; a disaster control officer and assistant qualified in radiation detection monitoring and survey; an information officer trained in the policies and procedures for handling news releases; a civil engineering representative capable of assessing damages to installations or civil property, and providing assistance in affected activities in early restoration; and flying safety officials, representatives of the Judge Advocate's Office, and other agencies as necessary. Because of the smallness in numbers of expertly qualified people in many of these areas, the more elaborately qualified teams will be found at higher headquarters level.

Suitable alternates for team members have been designated, and procedures are established for prompt activation of the team on a no-notice basis, 24 hours a day. Air transportation is available on standby, and experience has shown that, when required, the team may be activated and airborne within thirty minutes of receipt of information. Teams are equipped with radiation detection and environmental sampling equipment and protective clothing, suitably packaged for air transportation.

The base teams are supported by security personnel, medical personnel, fire fighters and other needed categories. The headquarters teams are responsible for assessing information on an incident and giving on-the-scene aid to base teams; observing base teams in action to evaluate their training and performance; and to provide liaison between Headquarters SAC and other agencies involved, such as the AEC, Public Health Service or locally responsible officials.

What then are the principal responsibilities and functions of the SAC Medical Service in response to a nuclear weapons accident? First, this component must provide the disaster control team chief and the CINCSAC with information on potential radiological exposure and other hazards that may be involved in these and other disasters. Second, there is a responsibility for advising or recommending precautionary measures, including radiation exposure criteria, acceptable tolerances to hazardous exposure, and control procedures. Third, to evaluate the monitoring and survey techniques used by subordinate disaster control personnel. Fourth, to insure that required personnel dosimetry and physical and laboratory examinations are accomplished when indicated on all team members, as well as all other personnel. Further, the information must be appropriately included in the field medical records of those individuals so involved.

Fifth, the industrial hygiene engineer is generally the chief of the monitoring element of the disaster control team and will supervise all necessary radiological monitoring accomplished by the team. Sixth, he also will operate air sampling equipment and will supervise collection of environmental samples for nuclear and chemical hazard analysis. Seventh, the provision of advice to the affected base and to other medical personnel on dosimetric procedures, physical and laboratory examinations, and environmental testing. Eighth, maintaining liaison with civilian health and medical agencies, such as the U. S. Public Health Service, state and local health offices, and civilian physicians. Ninth, in conjunction with operational and engineering representatives, the providing of advice on decontamination and other methods of hazard control. Tenth, insuring that required health physics and industrial hygiene procedures are undertaken during salvage and recovery operations.

What might then be the order of things to discharge these responsibilities in event of such an incident. While time does not permit detailed discussion of the many facets in, or connected with, the overall disaster control team response, it is worthy to briefly mention certain other facts not directly related to the medical service. Certainly, to have effective response it is important to have three specific and related command and control functions. These are: a workable, rapid communications system to provide an alert and to provide the necessary information for continuing direction of the control operation; a disaster control command post capable of assessing the situation and directing required measures for countering the affects of the disaster; and a well-trained and organized team at the site who arrive rapidly and work under the direction of a qualified on-the-scene controller.

Disaster control operations generally are in three phases, sometimes distinctly separated but more often overlapping or concurrent. The first of these is the discovery of the incident with alerting of responsible agencies, activation of disaster control teams and all other measures necessary to activate related operations. The second phase is the immediate reaction phase and includes fire fighting and other emergency measures to secure the area, evacuation of personnel, rescue and emergency medical treatment of casualties, precautions to prevent further damage to facilities or personnel, and assessment of the immediate radiation or other toxic hazard situation. The third phase is restoration of damage and can include salvage and recovery of weapon system components, removal and clearance of debris, decontamination of areas and material, repair of damaged facilities, and the environmental sampling and analysis that are required whether or not contamination has occurred.

The actions in an actual incident should proceed along the following lines. When notification is received the disaster control team should be alerted and the location of the incident should be pinpointed in a suitable map. Initial actions similar to those required for any other major aircraft accident or serious occurrence should be performed, amplified as necessary because of the increased hazard from the presence of the weapon. Medical service and other staff representatives should proceed to the disaster control command post, reporting to the disaster control officer. Ambulances and emergency personnel, such as security, fire fighters, sanitary and industrial hygiene engineers, emergency ordnance, disposal, etc., should be dispatched with radiation detection and environmental sampling and other emergency equipment.

The medical facility should prepare to receive casualties, and emergency surgical teams and other emergency treatment units should be activated. Normal hospital functions generally can continue. The medical facility should be alerted if the disaster appears to threaten

this facility by fire or detonation in its proximity. Other activities will be removing threatened aircraft or materiel. Medical service radiac instruments should be checked and readied for operation.

When the medical service team arrives at the scene, the senior representative will report to the on-the-scene controller and the team will prepare to receive casualties. Medical service monitors should perform radiation surveys jointly with other monitoring personnel, and the initial collection of environmental samples should be begun as soon as possible.

Air police and other security forces will maintain free and unhampered access for emergency vehicles, and at the same time restrict access to the area by unauthorized individuals. They will also be responsible for evacuating all disinterested personnel from within the 1500 foot minimum safe distance line. (This is the distance which has shown to be safe as far as blast and thermal effects are concerned.) If necessary, air police should be prepared to evacuate personnel in military or non-military sections adjacent to the incident. Medical service representatives must be prepared to advise regarding any contamination found and the significance of such contamination.

Should gamma emitting materials be present, the medical service will be responsible for advice on operations so that minimal dose, never to exceed 25 rem, be sustained. In this regard it can be noted that reading up to 50mr/hr may be detected from unfissioned weapon fragments.

Alpha monitoring should be started as soon as possible and if contamination is found, necessary decisions can be made calmly and without haste. If possible, air samples should be taken during all phases of response and recovery. These samples can be evaluated with field survey equipment and/or sent to the laboratory. Environmental samples should be collected at the same time and given the same treatment.

Patients should be monitored, but treatment should not be delayed solely because contamination is present on the clothing or the body. This contamination can be removed either after or during the required therapeutic procedures.

Medical service representatives, usually the sanitary and industrial hygiene engineer, should work with the civil engineering recovery team and make recommendations regarding temporary and/or permanent fixation of any contamination.

All requests for information and all contact with public news media should be through the base information officer's representative. Contact should be established with local and regional health officers for the purpose of apprising these authorities of the situation and its containment.

From this brief and very limited description, the following might be a checklist for the medical service participants. Medical representatives will insure that radiation, laboratory, sampling and allied equipment and supplies accompany the team. On arrival at the site, the radiation monitoring element, consisting of the industrial hygiene engineer and representatives of the operations and materiel directorates will verify the findings of any other teams or, in case no monitoring has been accomplished, proceed with these procedures.

The medical officer will supervise and/or collaborate on the care and examination of all injured personnel, and will make necessary records and observations thereto. If contamination is discovered, provision should be made for the collection of nasal swabs and urine specimens from team and allied personnel; these can be analyzed with field instruments but also must be submitted to the Radiological Health Laboratory.

Should gamma radiation be present, measures must be taken to preclude accumulation of a minimal dose, not to exceed 25 rem whole body. Whether contamination has or has not occurred, air samples will be periodically obtained. Environmental samples should likewise be taken, to include vegetation, water, swipes, and debris.

Should contamination have affected crops, food stuffs or water supplies, the disaster control team chief should immediately be so advised and the necessary liaison with public health agencies established. In the absence of this contamination the medical officer still should personally contact and/or accompany public health service representatives over the area as security permits.

The medical officer also will insure that any individual who may have been in a potential exposure situation be informed of the facts and the degree or potential of any possible harmful effects. Local physicians and health officers will be similarly apprised of the presence or absence of any hazards and the implications therefrom.

Information will be furnished by the medical representatives to the information officer as material for release to news media.

In the event the services of special organizations are required for salvage and recovery efforts, medical service representatives will observe and verify the adequacy of their monitoring and sampling procedures.

All clothing, equipment and other items used by the team or allied personnel will be evaluated and recommendations furnished regarding the handling and disposition of these items.

A subject in itself, and too lengthy for more than just mention at this time, is the added responsibility of all team members, but particularly the medical service, of consideration of the medico-legal aspects of disaster operations. Almost invariably these and related accidents are accompanied by personnel and property damage or destruction, facts that subsequently and easily lead to the submission of claims and suits. These damages may arise not only from the basic or primary accident, but as the result of minor, moderate or severe misadventures of the emergency responding elements. Therefore, all during the course of emergency response, consideration must be given to this important subject and its implications. Since a detailed discussion is not possible at this time, your attention is invited to an article in the August issue, Volume XXII, No. 4, of the Journal of the American Industrial Hygiene Association entitled "Medicolegal Aspects of Disaster Operations."

In conclusion, it can be said that although incidents involving nuclear weapons or their components will continue to be a matter of concern for military medical personnel and certain of their civilian colleagues, there are adequate means for coping with these situations. Prompt and positive response with professional competence is necessary in order to minimize public apprehension and insure that public health and safety are adequately protected. This response can be achieved only through knowledge, preparedness and training in all aspects of the problem, and through development of comprehensive and frequently rehearsed plans which have been studied and integrated at all levels.

NEW DEVELOPMENTS IN RADIAC INSTRUMENTS

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1. Introduction

a. The title of this presentation may be a misnomer as many of the devices for detecting and measuring radioactivity that I will comment on are not necessarily new from the standpoint that they have just been developed. Some have been under constant development or modification for some time now and others have not been considered, as yet, for use by the Air Force as standard radiac. Some of the devices that I will discuss have been in use for some time now but may not be familiar to some of you.

b. For those of you who are not familiar with the term "RADIAC", I will start by translating this term.

R - radio)
) or radiation
A - activity)

D - detection

I - indication

A - and

C - computation

The term RADIAC may be used either as a noun or an adjective; for example, beta gamma radiac and radiac set.

c. The radiac instrument itself is usually referred to as a radiacmeter. When a radiacmeter is assembled in a case with spare parts, extra batteries, headphones, shoulder harness, calibration check source, etc., it is called a radiac set.

d. The terms dosimeter and dose-rate meter or survey meter are frequently used in place of the general term radiacmeter.

(1) A dose-rate meter or survey meter such as the G-M, ionization chamber or scintillation type, is a radiacmeter that indicates the intensity of radiation in terms of mr/hr or mrad/hr. It is likened to the speedometer on your car which tells you the rate of speed you are traveling.

(2) A radiacmeter which integrates the dose rate over a period of time in roentgens or rads is sometimes called a dosimeter or personnel meter. It tells you the total dose one has received. This is likened to the odometer on your car. For example: The film badge and self-reading and non-self-reading dosimeters or pocket ionization chambers.

2. Principles of Operation of Radiacmeters

a. All methods of radiation detection are based on the ability of radiation to cause ionization or excitation of an atom. Ionization occurs when an atom gains or loses an electron. Excitation occurs when an electron merely jumps into a higher energy orbit around the same atom and gives off energy in the form of a pulse of electromagnetic radiation when it falls back into its normal orbit.

b. Radiacmeters vary only in the medium in which the ionization or excitation is permitted to take place and in the method by which this ionization or excitation is detected and indicated. There are five classes of media in general use at the present time for radiation detection. These are as follows:

- (1) Radiophotoluminescence media (phosphate glass dosimetry).
- (2) Photographic emulsions.
- (3) Chemical decomposition media.
- (4) Scintillation media (phosphors such as cadmium sulfide, silver-activated zinc sulphide, anthracene, naphthalene, stilbene and thallium activated sodium iodide).
- (5) Gases (air, argon, methane, propane, etc.).

c. Since the neutron is an uncharged particle and does not produce ionization directly, neutron detection must be based upon the measurement of secondary effects which produce ionization.

3. Radiophotoluminescence.

a. Radiophotoluminescence is a phenomenon exhibited by certain materials such as the silver activated phosphate glass used in the DT-60B/PD dosimeter and in the ORNL Badge which, after being subjected to ionizing radiation, fluoresce under ultra-violet light in a spectral region different from the region in which they fluoresce before irradiation.

(1) When the glass is exposed to ionizing radiation, loosely bound electrons are freed from negative ions and migrate through the

glass. Some of them are trapped by interstitial silver ions to form a special type of F-center. This F-center or photoluminescent center can be excited by ultra-violet light and it then returns to ground state by emitting a photon in the red region.

(2) The intensity of the luminescence under ultra-violet light is proportional to the amount of radiation the glass has received. The property of radiophotoluminescence after irradiation represents a permanent change in the spectral characteristics of the glass. Therefore, this property may be utilized to advantage in fairly high range dosimeters.

b. DT-60B/PD Personnel Dosimeter

(1) SLIDE NO. 1 shows the new DT-60B/PD personnel dosimeter. Improvements include:

- (a) Elimination of volatile and fluorescent materials.
- (b) Improvements of the optical surfaces of the glass.
- (c) Replacement of painted black surfaces by fritted surfaces which should not peel; and
- (d) A different lead shield configuration to improve the directional dependence.

(2) In the old model, lead is only on both sides of the glass and does not cover the entire glass volume, as it does in the new model. Difficulties were experienced in the old model due to fluorescence in the seal ring and cement. Peeling of the black surfaces and the rough glass surface also caused erroneous readings.

(3) Phosphate glass dosimeters are highly sensitive to thermal neutrons, but are essentially insensitive to fast neutrons. The Los Alamos Scientific Laboratory is investigating ways to shield phosphate glass dosimeters with Lithium-6 in hopes of making them insensitive to thermal neutrons.

(a) Such a dosimeter would be useful in certain special, but perhaps uncommon, situations where one might expect a high dose of neutrons without a lethal dose of gamma radiation. It is not expected that the entire inventory, if any, of the DT-60 dosimeter will be so modified because of the cost of Li-6 and because of the increase this would cause in the size of the dosimeter.

(4) The DT-60 has a sensitivity of 0-600r with a minimum detectable dose of 10r. It has an accuracy of $\pm 20\%$ from 80 Kev to 1.5 Mev. The CP-95A/PD reader, which operates from a 115 volt A-C power

supply, is required for reading the non-self-indicating personnel dosimeter.

- (a) The CP-263/PD reader, which is battery operated, is presently being tested.

(5) Manufacturing difficulties have prevented the new DT-60B from going into production.

4. Photographic Emulsions With Added Devices

a. Film badges of various types have been used since the beginning of the Manhattan Project. The mode of inter-action of radiation with the photographic emulsion is that of ionization.

(1) When light or other electromagnetic waves strike the emulsion, some of the silver halide atoms of the emulsion are reduced to free silver atoms which constitute the so-called "latent" image. This image is developed by a suitable reducing agent (developer) and a fixing solution is used to dissolve the residual silver halide grains. The degree of blackening achieved depends on the emulsion characteristics and processing conditions as well as the exposure to radiation.

(2) The degree of darkening is measured in terms of its optical density. This darkening is proportional to the energy of the radiation and the radiation dose received by the film.

(3) Photon energy dependence of film emulsion has been a problem of prime concern, and many methods for overcoming or circumventing this characteristic have been developed. In all cases, this has been accomplished by a system of filters or absorbers combined into a package or "badge" which contains the film packet.

(4) If only low level neutron doses are to be encountered, a nuclear track emulsion can be included to complement the dosimeter film packet.

b. ORNL Badge Dosimeter (Personnel Meter)

(1) SLIDE NO. 2 shows the most recent model of the ORNL Badge Dosimeter just put into use at ORNL this year.

(a) This badge is constructed of a butyrate plastic and is held to the clothing by a standard alligator clip. When fully assembled, the badge weighs approximately 33 grams and has overall dimensions as follows: 2-1/2" x 1-3/4" x 5/16".

(b) The badge utilizes films and filters for routine

monitoring and films plus foils, phosphate glass, and chemical dosimeters for high level monitoring. For neutron dosimetry, the badge must be supplemented with Threshold Detector Units, which will be discussed later.

(2) DuPont film packet 553 is used for recording darkening caused by beta, gamma and x-radiation through 4 filters in the front of the badge (cadmium, aluminum, and two thickness of plastic), plus 2 additional filters (lead and plastic) in the rear of the badge which are arranged in such a manner as to allow for adjustments in the event that the exposure is delivered to the back of the badge.

(a) Film density measurements behind the cadmium and aluminum filters provide penetrating radiation dose data.

(b) Measurements behind the 2 plastic filters provide data for determination of the moderately penetrating radiations.

(c) The DuPont film packet 553 has a "hard" gamma dosage range of 50 mrad to 500 rads. Dosage above this range can be determined from the phosphate glass which has a range up to several thousand rads and from the chemical dosimeter which has a range up to 10^6 rads.

(3) Routine dosimetry is accomplished through use of Eastman Type A film, which is found to have a maximum usable range of approximately 20 mrad to 10 rads from 3 Mev neutrons.

(a) For reliable neutron dose analysis above 10 rads, the use of the sulfur, two gold foils with one of the foils surrounded by cadmium, and an indium foil is required.

(b) The thermal flux is determined by the difference in activation between the two gold foils, one of which is surrounded by cadmium.

(c) The neutron flux having energies greater than 2.5 Mev is determined by measuring the activation on the sulfur pellet.

(d) The indium foil is very effective as a personnel screening device. Immediately following a nuclear accident, those persons who have received significant exposure to neutrons may be segregated easily by measurement of the radiation from the activated indium foil. This can be done with a portable G-M survey meter if readings are taken within 4 hours of the accident. The activated gold serves to identify the persons exposed to neutrons. Although it is less sensitive than the indium, it serves as a valuable complement, since it has a much longer half life than the indium.

c. Hurst Threshold Detector Units (TDU)

(1) SLIDE NO. 3 shows the Hurst Threshold Detector Unit which provides an estimate of the neutron spectra in 5 energy regions. You will recall that HB-63 shows that the RBE varies for different neutron energies. Therefore, the intensity of the various energies in the neutron spectrum must be known to compute the dose.

(a) In the Hurst TDU, a Boron-10 shield is used to avoid thermal neutron activation of the Np-237, U-238 and Pu-239. The cavity is lined with 25 mil cadmium to capture neutrons which may be moderated by the boron.

(b) The fast flux and energy distribution of neutrons are determined by fission and activation analysis of Pu-239, Np-237, U-238, and a S-32 pellet in the ORNL badge, which together provide measurements of flux above 1 kw, 0.75 Mev, 1.5 Mev and 2.5 Mev, respectively.

(2) The TDU's, along with the ORNL badge are located in fixed positions in areas where nuclear accidents are considered possible. They are placed so that the neutron and gamma environments of the accident may be reconstructed.

(a) The sulfur and gold components of the badge are activated by neutrons such that counting techniques permit determination of the thermal neutron exposure from the two gold foils, and high energy (greater than 2.5 Mev) neutron exposures from the sulfur.

(b) Exposure to intermediate energy neutrons is determined by normalizing the data from the badge to that of the TDU located in the vicinity of the badge wearer, or by fitting the data from the badge to the spectrum at the point of exposure, if such is known.

5. Chemical Decomposition Media Radiometers

a. As radiation is capable of causing ionization, it is possible to use the ionization produced in a chemical system as an indication of the amount of radiation received.

(1) This is done in the case of chemical decomposition indicators wherein ions produced by radiation combine chemically to form new compounds or to change chemical characteristics from those existing in the pre-irradiation stage.

(2) An inherent drawback of chemical decomposition systems is the fact that the sensitivity to radiation is quite low. It requires on the order of 25 roentgens of x- or gamma radiation before any detectable chemical change is induced. Consequently, these systems are best suited for measuring the dose from large sources of radiation or for nuclear accident or disaster control monitoring purposes.

b. USAF Chemical Dosimeter

(1) SLIDE NO. 4 shows the TCE (tetrachloroethylene) two-phase USAF Chemical Dosimeter.

(a) This two-phase chemical dosimeter is prepared by overlaying tetrachloroethylene (perchloroethylene) with a dye water solution. Anhydrous tetrachloroethylene responds to x- and gamma radiation to produce water soluble hydrochloric acids in proportion to the radiation absorbed. This formation of acid decreased the pH. By using a suitable indicator such as Chlor Phenol Red, it is possible to ascertain the absorbed dose by visual comparison or color change against a standard, by back titrating with a standard base, or by spectrophotometric evaluation. The spectrophotometric technique offers the greatest accuracy and the ampoules do not have to be opened as they do in the titration method. Thus more permanent records are available.

(2) The TCE dosimeter system provides for measuring dosages over a range of 25 to 2×10^6 rads in a mixed radiation field. With the addition of a stabilizing agent, such as Ionol, the TCE is rate independent within $\pm 8\%$ from 0.5 rad/hr to 10^{12} rad/hr. The system is also temperature independent within $\pm 5\%$ from 5°C to 55°C. Energy independence is within $\pm 8\%$ from 90 Kev to 10 Mev. The shelf life is greater than 9 months.

(3) As fast neutron sensitivity is proportional to water solubility of the TCE, this two-phase dosimeter is made relatively insensitive to fast neutrons since the solubility of TCE in water is less than 0.01%.

(a) The TCE two-phase system is, however, sensitive to thermal neutrons due to the high thermal neutron cross section for chlorine. This response can be reduced by shielding with Lithium-6.

c. TCE Dosimeter System

(1) SLIDE NO. 5 shows the TCE Dosimeter system with Lithium can and blast-shield assembly.

(a) Five TCE ampoules are used to cover various portions of the dose spectrum from 25 to 30,000 rads.

6. Scintillation

a. There are certain substances such as cadmium sulfide, zinc sulfide, anthracene, and sodium iodide, which emit light (fluoresce) when bombarded by ionizing radiation. These substances are called phosphors.

(1) The principle of scintillation detection of radiation is based on the fact that phosphors scintillate when subjected to ionizing radiation.

(a) The incident radioactive particle or photon excites the molecules of the crystal or phosphor. The phosphor de-excites and gives off a flash or photon of light in the visible range. The intensity of light is proportional to the number and energy of the photons or particles striking the scintillation media.

(b) These light flashes fall on the photocathode of a photomultiplier tube and eject photoelectrons, which are then further amplified by the process of secondary emission at the dynodes of the tube. Output pulses may be further amplified and applied either to a scaler or to a counting rate meter.

b. NRDL Wrist Dose Rate Meter

(1) SLIDE NO. 6 shows the NRDL Wrist Dose Rate Meter.

(a) This all solid-state type radiacmeter has a case approximately 2-inches in diameter and less than 1-inch thick. It is designed to measure gamma radiation between 1 and 500 r/hr, and uses a cadmium sulfide phosphor for detecting this radiation.

(b) This wrist dosimeter is completely waterproof, and all electronics are self-contained, including the power source, which is a pair of rechargeable nickel-cadmium storage cells. Recharging is accomplished by connecting the charging plug to the recessed terminal on the bottom of the case to a 110 V A-C, D-C supply, two flashlight cells, or possibly a solar battery which might even be mounted integrally with the case.

(c) To set the unit in operation, the outer ring is rotated to the highest range, 0-500 r/hr. If the meter deflection is too low, the switch is rotated to ranges in a clockwise direction until the desired deflection is obtained. The meter has 3 ranges of radiation intensity: 0-5, 0-50, and 0-500 r/hr. The range ring may be rotated in either direction with no damage to the instrument.

(d) Calibration is maintained with $\pm 15\%$ for all combinations of temperature (-40 to $+50^{\circ}\text{C}$), humidity (0-100%), and battery condition (1.15-1.35V).

C. PAC-1S With Pu-Gamma Probe

(1) SLIDE NO. 7 shows the Eberline PG-1 plutonium-gamma probe for the PAC-1S alpha scintillation counter. This radiac is used for the detection of low energy photons emitted from areas contaminated with plutonium. It is especially useful for detecting Pu-239 under adverse conditions, such as moisture or leaching of Pu in soil and absorption due to dust coverage, when alpha particle detection is impossible. It can also be used as a monitor for Pu- contaminated puncture wounds.

(a) The probe for this radiacmeter consists of a 1mm thick thallium activated sodium iodide scintillation crystal with a 1 ml aluminum window, backed by a Dumont 6467 photomultiplier. The probe works directly from either an Eberline model PAC-1S or PAC-1SA portable alpha counter.

(b) The characteristic x-rays of Pu-239 are capable of penetrating moderate thickness of water or human tissue (0.8cm will absorb 50%) and therefore offer a means of externally detecting Pu-239 contamination that may be inside a wound or shielded by a damp surface.

(c) Eight different levels of x-ray energy in the 14 to 21 Kev region are reported for Pu-239. These x-rays are produced by the internal conversion of 51- and 37- Kev gamma radiation associated with the alpha decay of Pu-239. The high internal conversion for the 51- and 37-Kev gamma radiation of Pu-239 and the low abundance of other gamma radiation indicate that the detectable x-rays will be more intense than the gamma radiation. Therefore, a scintillation-type monitor that is selective to the 14 to 21 Kev x-rays appears to offer the most promise in detecting small amounts of Pu-239.

(d) The 1mm thick crystal on the PG-1 probe makes the scintillation crystal energy selective. It has a high absorption efficiency (99%) for x-rays in the 14 to 21 Kev region, and low efficiency (40% at 100 Kev, 7% at 200 Kev) for high energy background.

(e) By holding the probe with the crystal end up and reading the count rate, then by turning the probe over and again reading the count rate, the difference between the two readings is the count rate due to low energy gamma photons. Unfortunately, it is very difficult to calibrate this device due to the effects of high

background radiation and due to the 60 Kev photons from Americum-241, the daughter of Pu-241.

d. Model WM-1 Plutonium Wound Monitor

(1) SLIDE NO. 7 shows the Eberline Model WM-1 Plutonium Wound Monitor which is battery operated (5 RM-42 mercury batteries) and housed in a case 11" long by 8-3/4" high by 4-1/2" deep. The probe is the same as the PG-1 probe and with the PAC-1S counter.

(2) In addition to obtaining energy selectivity through use of a thin (1 mm) scintillation crystal, this wound monitor can control channel width by the use of two separate trigger circuits. The electronics are not that of a linear pulse height analyzer, however.

(a) The channel width is a function of the Channel Level control setting, increasing as the Channel Level control is increased. The Channel Level control is a gain control on the amplifier. The output pulse from the amplifier is fed into two separate trigger circuits. Trigger 1 has a fixed sensitivity, while the sensitivity of trigger 2 can be adjusted by the Channel Width control. The sensitivity of the two triggers is approximately the same with the Channel Width control set at zero. As the control is turned up, the trigger 2 becomes less sensitive, i.e., it takes a larger pulse to trigger it. This results in a range of pulse heights which will trigger number 1 but not number 2. The output from the two triggers is fed through emitter followers for isolation, and into a differential amplifier. When a pulse is obtained, from Trigger 1 only, the difference amplifier puts out a pulse to a count rate trigger. This reduces background pulses or pulses due to high energy radiation.

7. Radiacmeters Using Gas Medium for Detection of Radiation

a. Radiacmeter detectors using a gas medium (air or special mixtures) as the method of radiation detection consist of an enclosure filled with the gas and two conductors, the anode and the cathode, which are insulated from each other and upon which is impressed an electric field produced by raising the potential of one conductor over the other. When the gas enclosure is in a radiation field, the photons (x- or gamma-radiation) or charged particles (alpha and beta) ionize the gas between the electrodes, and these ions are attracted to the electrodes causing a flow of current or discharge of the enclosure or chamber if it is used like a condenser ion chamber.

(1) The magnitude of this current is proportional to the radiation dose rate and is measured by suitable electrometer circuits. The chamber wall material and thickness, and the filling gas mixture and pressure along with the design of the chamber, determine the response of the radiacmeter to the various types and energies of ionizing radiation.

b. "Chirpee" Personal Radiation Monitor

(1) "Chirpee" shown in SLIDE NO. 10 is a miniature, lightweight (3-1/2 oz.) radiation monitor that warns the user when he encounters an unexpected radiation field. Both visible and audible warning signals are produced. A neon lamp at the top of the instrument flashes at a rate proportional to radiation intensity. A hearing aid earphone at the base of an air column that exists through an opening in the side of the case chirps at the rate proportional to radiation intensity.

(a) In the normal background of cosmic and natural radiation, the lamp will flash and chirp once every minute or two. In a field of 10 mr/hr. the lamp will flash and chirp about four times a second. The flashing rate increases with radiation intensity until a saturation rate of 3,000 to 4,000 flashes per minute is reached in fields of 1 to 10 r/hr. This permits the location of radiation sources or the choosing of the best evacuation route in case of a radiation accident.

(b) An important characteristic of the monitor is the ability to maintain the alarm signals even when the radiation level has drastically exceeded the upper limit of its dynamic range of indication. Tests have shown that the saturation alarm rates that are reached between 1 and 10 r/hr are maintained as the intensity rises to at least 3×10^6 r/hr.

(2) The radiation detector used for "Chirpee" is a miniature Geiger-Mueller counter of the halogen-quenched type. It has no "on-off" switch, but is turned off merely by inverting the unit. The battery is disconnected electronically by means of a mercury switch. Thus, battery life can be extended from 6 weeks of normal continuous use to over 6 months of 8-hour-per-day operation under normal background conditions. As long as the monitor is worn, there is no danger of having it accidentally in the "off" position at a critical moment.

c. Beta-Sensitive Personnel Dosimeter

(1) SLIDE NO. 9 shows the beta-sensitive personnel dosimeter developed by Harry H. Hubbell at ORNL in 1957 which has just been marketed by Victoreen Instrument Company.

(2) This is the first time a beta-sensitive personnel dosimeter, other than a film badge, has been made available commercially. The original ORNL design shown in this slide is similar to the Victoreen pocket chamber with the exception that the chamber wall is made of aluminum or magnesium with about 50% of the surface area perforated. The inner wall of the ORNL design is made of 7 mg/cm² conducting paper which approximates the thin portions of the epidermal layer of the skin. Thus, any beta dose measured inside this wall is essentially equal to the maximum dose received by the germinal layer of the skin. This personnel dosimeter has a beta response of at least 50% of the true dose received by the germinal layer of the skin through an epidermal layer of 7 mg/cm². Multiplying the reading by two gives the maximum beta dose received.

(3) The commercial version of this beta-gamma dosimeter uses an aluminized mylar film for the inner wall. By wearing two dosimeters, one perforated and the other not perforated, one can determine differential beta-gamma dose by subtracting the non-perforated dosimeter reading from the perforated dosimeter reading and multiplying by two. The range of these dosimeters is from 0 to 200 mrad.

d. Pillbox Wrist Dosimeter

(1) Harry H. Hubbell, Jr., et al, at ORNL in 1960, released a design for a wrist dosimeter which is shown in SLIDE NO. 11. The device is a shallow pillbox about an inch and a half in diameter and five-eighths of an inch high.

(2) As shown in SLIDE NO. 12, the outside is a ribbed nylon cover with 50% open area on the top and sides, and having a vinyl liner 7 mg/cm² in density, coated inside with colloidal graphite, to define the sensitive volume. The insulated electrode, on the inside of the base, also is graphite coated. Electrical contact is made by a rivet through the base. A metal base and the graphite coating on the liner form the outer, grounded electrode.

(3) The final design was tested with heavily filtered x-rays and radium gamma photons and showed a constant response within about 20% from 20 Kev to 700 Kev. The wrist dosimeter was also exposed to beta-particles from radioactive water solutions having effectively infinite thickness. The electrons striking the chamber had average energies from 52 to 694 Kev. The device showed an approximately constant response to beta-particles of 50 ±13% over the whole energy range when compared to the dose to the basal layer of the epidermis.

e. AN/PDR-52 Radiacmeter

(1) SLIDE NO. 13 shows the AN/PDR-52 radiacmeter now under development and testing by the U. S. Naval Radiological Defense Laboratory. This is the first radiacmeter designed for use by the Defense Department to measure beta dose rate in the presence of gamma-radiation.

(2) The AN/PDR-52 radiacmeter is a dual ion-chamber type instrument designed for detecting, indicating, and measuring:

- (a) Beta radiation in the presence of gamma radiation.
- (b) Beta and gamma radiation combined, and
- (c) Gamma radiation in the presence of beta radiation.

(3) SLIDE NO. 14 shows the bottom beta-sensitive ion-chamber with window open and closed. This chamber is fitted with a thin window (7 to 11 mg/cm²) which permits beta particles of about 100 KeV to greater energy to penetrate to its gas volume. This gives the beta chamber a "skin dose" measuring capability. The other ion chamber, located above the beta sensitive chamber, is essentially insensitive to beta particles because of the relatively heavy shielding around it.

(4) Since the two ion-chambers are virtually identical insofar as interaction with gamma radiation is concerned, both ion chambers will produce nearly equal electrical currents. Therefore, the detection of beta radiation in the presence of gamma radiation is accomplished by polarizing oppositely the ion collection potentials supplied to the two ion chambers so that the essentially equal electrical currents produced by the two chambers are opposite in sign for gamma radiation and thus cancel. Any remaining ion current produced by beta radiation in the beta chamber is then alone sensed by the electrometer.

(a) The AN/PDR-52 detects beta and gamma radiation together by using only the top ion chamber.

(5) The maximum range is 0 to 1000 rad/hr measured in 4 ranges: 0-2; 0-10; 0-100; 0-1000 rad/hr. The radiacmeter is equipped with a push button operated 0.5 millicurie Sr-90 check source. Overall accuracy is $\pm 20\%$. The radiacmeter weighs 6 lbs, 2-1/2 oz. It is 9-1/2 inches long, 4-1/2 inches wide and 4-3/4 inches high.

f. Cutie Pie (CP-3DM)

(1) SLIDE NO. 15 shows the CP-3DM "Cutie Pie" manufactured by El-Tronics, Inc., which is a NRDL modification of their standard Cutie Pie. The ionization chamber consists of a central electrode sealed in an air atmosphere within a 1/32-inch polyethylene wall. A 1/4-inch thick molded polyethylene boot or shield is provided with the radiacmeter to differentiate between beta and gamma radiations.

(a) With the polyethylene boot in place, the radiacmeter detects gamma and less than 13% beta-particles having an energy greater than 2 Mev. With the shield removed, both beta and gamma are detected. The beta reading may be determined by subtracting the gamma reading from the beta-gamma reading. For general monitoring purposes, the beta reading is a relative indication of the true beta dose within $\pm 20\%$. This Cutie Pie has a minor beta directional sensitivity and maximum response to beta of energies above 0.3 Mev. It is designed specifically for the measurement of beta and gamma radiation from fission products.

(b) The energy dependence for x- and gamma-radiation response for this radiacmeter is excellent. An error of less than 10% is involved through an energy range of 20 Kev to 2 Mev. Thus, this is a very fine radiac for monitoring x-ray facilities. It is also a good radiacmeter for evaluating x-ray exposures from the operation of electronic power tubes at radar sites such as the hydrogen thyratron, magnetron, and klystron tubes which operate at voltages from 5 K vp to 400 K vp. The electronic circuit of the Cutie Pie should, however, be shielded from the effects of radio frequency (RF) waves.

(c) The range of this radiacmeter as shown on this slide is in 4 ranges from 0-100 r/hr. A fifth pot may be installed or one of the pots changed so that the lowest range can be from 0 to 10 mr/hr. The standard 4 ranges are from 0-100 mr/hr, 0-1 r/hr, 0-10 r/hr and 0-100 r/hr.

g. ORNL Paper Chamber Cutie Pie

(1) SLIDE NO. 16 shows the ORNL Paper Chamber Cutie Pie. This ORNL modification of the Cutie Pie manufactured by El-Tronics has three ranges: 0-100, 0-1000, and 0-100,000 mr/hr. Wave length dependence is $\pm 10\%$ for gamma and x-rays having an energy spectrum of 10 Kev and 2 Mev.

(2) The paper chamber is made as shown in SLIDE NO. 17. The bakelite shell has a thickness of 1/16-inch. The paper thickness is 7 mg/cm². The open area covered by the 7 mg/cm² conducting paper thickness is approximately 50% of the total bakelite shell area. Thus, any beta dose measured through this 7 mg/cm² paper is essentially equal to the maximum dose received by the germinal layer

of the skin. A meter reading gives the total gamma exposure dose rate and approximately 50% of the beta exposure dose rate which has energies capable of reaching the basal layer of the epidermis; i. e., beta-particles with energies greater than 70 Kev. The 13-week rule which permits 3 rads of gamma or 6 rads of beta radiation in 13 weeks can be adhered to if the paper chamber dose rate meter does not give a reading greater than approximately 6 mrad/hr for a 40-hour work week. In other words, the dose rate meter gives an effective total beta and gamma dose.

(3) One of the problems with the paper chamber Cutie Pie is that electronic equilibrium is not reached for gamma radiation with the paper chamber. A thin walled ionization chamber placed near a gamma source; i.e., within the range of the secondary electrons will give a reading in roentgens that is too low, because the secondary electron radiation has not reached equilibrium with the primary gamma radiation. Another disadvantage with the paper chamber is that it is more subject to humidity than the standard Cutie Pie Chamber or the polyethylene chamber used in the CP-3DM Electronics model. This CP-3DM model, however, is not satisfactory for measuring beta-particles having energies below 0.3 Mev.

(4) The Cutie Pie type radiacmeters operate in the ionization chamber region where the current produced by ionization is proportional to the rate at which primary ions are formed in the detector, and the voltage across the load resistor is proportional to the intensity of the radiation measured in dose rate units. This type of radiacmeter, therefore, becomes a true dose rate meter, as it considers intensity and type of radiation.

h. AN/PDR-27J Radiacmeter

(1) SLIDE NO. 18 shows the latest model of the AN/PDR-27 radiacmeter. This model has the following improvements over previous AN/PDR-27 models:

(a) Both G-M tubes can be removed from the mounting well for close-range detection of radiation. You will recall that in the older models, the high range probe is located inside the instrument case above the dimple in the bottom of the case.

(b) Six 1-1/2 volt dry cell batteries connected in series furnish all the source power necessary for operation of the instrument. At 77°F, these batteries can power the radiacmeter for approximately 40 hours of continuous operation. A transistorized power supply converts the 9 volt d-c power from the batteries into a regulated 700 d-c power supply which is fed to the G-M tube in the detector circuit.

(2) The major disadvantage of this radiacmeter is that it will saturate and read zero in high radiation fields. The maximum range of 5 mrad/hr for open window beta-gamma readings is also an undesirable limitation.

i. AN/PDR-43A Radiacmeter (Pulsed Geiger Survey Meter)

(1) SLIDE NO. 19 shows the AN/PDR-43A radiacmeter which is a major advancement in G-M type radiacmeters. This instrument will not saturate and read zero in high radiation fields. It is a "pulsed" (time controlled) end-window G-M type radiacmeter with Geiger tube housed within the instrument case for measuring gamma radiation and detecting beta radiation.

(a) The maximum range is 500 r/hr measured in three ranges: 0-500, 0-50 and 0-5 r/hr. The meter face changes with the position of the range selector switch showing three linear color-coded scales. Beta-gamma radiation may be detected on these ranges by properly positioning the function selector disk (beta shield-source disk) located on the bottom of the instrument case.

(b) An 80 microcurie Krypton-85 source, sealed in thin wall tubing and permanently bonded in recess of function selector disk, is used to check the instrument ranges for response to radiation.

(c) Power is supplied for this radiacmeter by two 1-1/2 volt dry cell batteries connected in series and having a useful life of approximately 45 hours. The radiacmeter consists principally of a transistorized power supply, A G-M mica end-window tube housed within the instrument case, a non-jamming circuit for pulsing the Geiger tube on a preset period of time, and a computer indicator circuit which provides a meter reading which is proportional to the radiation field intensity irradiating the G-M tube detector element.

(d) The gamma accuracy is $\pm 20\%$ of true intensity from 10% full scale to full scale on each range over a temperature range of -4°F to $+122^{\circ}\text{F}$. The energy response varies within 20% from 80 Kev to 2 Mev. It is not affected by humidity nor altitude.

j. Model EP-271 Pulsed Geiger Survey Meter

(1) SLIDE NO. 20 shows the model EP-271 Pulsed Geiger Survey Meter designed by Electronic Products. This radiacmeter combines the basic electronics of the AN/PDR-43A with the thin end-window G-M probe of the AN/PDR-27 to obtain an instrument for measuring gamma radiation up to 500 mr/hr in 4 decade ranges (0.5, 5, 50, and 500).

(a) As in the AN/PDR-27, beta-particles having energies greater than 50 Kev are detected, and alpha particles having energies greater than 5 Mev are detected. As in the AN/PDR-43, this G-M radiacmeter does not saturate and read zero in high radiation fields. It employs the same "pulsed" (time-controlled) non-jamming circuitry principle as the AN/PDR-43A.

(b) With the end-window G-M probe similarly designed to the specifications for the AN/PDR-27C end-window probe, gamma accuracy is $\pm 20\%$ of true intensity from 10% full scale to full scale on each range over a temperature range of -20°C to $+50^{\circ}\text{C}$. The energy response from 80 Kev to 2 Mev is flat within $\pm 20\%$.

(2) This radiacmeter provides an excellent complement to the AN/PDR-43A which cannot read gamma radiation accurately below 500 mr/hr and eliminates the requirement for the AN/PDR-27. A set of headphones is furnished as an accessory to the instrument to provide a means of monitoring aurally.

k. Model E-500B Geiger Counter

(1) SLIDE NO. 21 shows the Eberline Model E-500B Geiger Counter. This radiacmeter has non-jamming circuitry which prevents saturation of the instrument in gamma fields up to 1000 r/hr.

(a) The E-500B is a transistorized portable Geiger counter designed for monitoring beta-gamma radiation up to 200 mr/hr. Gamma radiation may be monitored up to 2 r/hr. Five linear ranges of 0-0.2, 0-2, 0-20 and 0-200 mr/hr for beta-gamma; 0-2000 mr/hr gamma only are provided. Earphones are provided for monitoring aurally.

(b) Two different detector tubes are used in this radiacmeter as are used in the AN/PDR-27 radiacmeter. One small volume tube is located inside the instrument case and is used only on the 0 to 2000 mr/hr range for measuring gamma radiation only. The other detector tube is mounted in an external probe and is used for beta and gamma radiation on the four lower scales.

(2) The side-window G-M external tube on this radiacmeter is superior to the end-window G-M probe for rapid beta-gamma screening of contaminated personnel. The side-window tube with window closed does not have the good energy independent characteristics that the AN/PDR-27C end-window G-M probe has.

8. Neutron Radiacmeters

a. Monitoring of neutron radiation fields is a complex undertaking. In order to make an accurate evaluation of the rem dose rate, the complete energy distribution must be measured. At the present time, there are no portable radiacs, military or commercial, capable of measuring the complete neutron spectrum. At best, one may detect either slow or fast neutrons but not intermediate neutron energies.

(1) Since neutrons have no charge, they do not react with electrons to produce ionization. It is, therefore, necessary to use indirect or secondary means to detect neutrons. To do this, the following two types of interactions are used:

(a) Nuclear Reaction - A slow neutron enters the counter and reacts with a boron isotope of mass 10. The boron-10 isotope is capable of capturing slow neutrons, that is neutrons with energies less than 1 ev, because the cross section or probability for this reaction is extremely small for fast neutrons. The boron which is in the ionization chamber may be either in the form of a gas such as boron trifluoride or in the form of a thin coating of boron or a boron compound on the sides.

1. The boron-10 atom absorbs the slow neutron in its nucleus, thus raising its mass by one, becoming boron-11. Boron-11 is unstable and breaks into two pieces, lithium-7 and an alpha particle which produces the measurable ionization.



2. Fast neutrons can be moderated by a paraffin moderator into thermal neutrons so that they can be absorbed in a boron-filled chamber operating in either the ionization or the proportional region but not in the Geiger region so that alpha pulses may be discriminated from the smaller pulses produced by gamma photons. A cadmium shield is sometimes used to absorb the slow neutrons while the paraffin moderates or slows down the fast neutrons so that they will react with the B-11 nuclei.

(b) Recoil Reaction (Elastic Scattering) - The recoil reaction for detecting fast neutrons is based upon the principle of elastic scattering; that is, a neutron colliding with a proton in polyethylene or other hydrogenous material and transferring its momentum to the proton. The proton, in turn, then produces ionization which can be measured by a proportional counter.

b. AN/PDR-49 Neutron Detector

(1) SLIDE NO. 22 shows the AN/PDR-49 Neutron Detector. This radiacmeter uses a BF_3 gas-filled chamber for proportional counting. The boron gas is enriched in the B-10 isotope. Thermal and slow neutrons with energies less than 1 ev react with the B-10 producing Li-7 and an alpha particle which produces the measurable ionization.

(a) For fast neutron monitoring the BF_3 tube is covered by a cadmium-shielded wax monitor. The cadmium absorbs the thermal neutrons and the wax moderates the fast neutrons to thermal neutrons which react with the B-10.

(2) The probe contains two mercury batteries, a pre-amplifier, and a control switch in addition to the BF_3 tube and the cadmium shield and wax monitor. The radiacmeter cast contains a meter which indicates $\text{n/cm}^2\text{-sec}$ from 0 to 250 and must be multiplied by the range selector setting which has OFF, X100, X10 and X1 positions. This gives the radiacmeter a range of 0 to 25,000 $\text{n/cm}^2\text{-sec}$ for a radium-beryllium neutron spectrum.

(3) Other features of this radiacmeter are as follows:

(a) Meter response switch with long (15 sec) and short (4 sec) time-constant positions.

(b) A receptacle for earphones.

(c) A receptacle for the probe head.

(d) A calibration switch.

(e) Pilot light regulator (neon light indicates that power is applied).

c. AN/PDR-47 Fast Neutron Detector

(1) SLIDE NO. 23 shows the AN/PDR-47 Fast Neutron Detector. This radiacmeter employs a proton-recoil proportional counter for the detecting and measuring of fast neutrons (10 Kev to 10 Mev). The range of this detector is 0 to 500 mrad/hr. A single five-position selector turns the radiac to "INT", "O", 500, 50 and 5. For readings below those readily readable on the 0-5 range, or for measuring of accumulated dose, the range switch is placed on the "INT" position. A scale for accumulating 200 counts is on the meter. Dividing the accumulated count by the time in seconds gives mrad/hr exposure.

(2) The following additional features are provided:

(a) A battery switch with five positions: OFF, WAIT, ON, BATT CHECK 1, and BATT CHECK 2.

(b) A zero control to zero the vacuum tube voltmeter circuit.

(c) A receptacle for earphones.

COMPARISON OF PAC-1S AND PAC-3G

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Santa Fe, New Mexico

INTRODUCTION

The comparison of the PAC-1S and PAC-3G portable alpha counters is more easily understood when one considers the design criteria behind each instrument. It is essential, also, to understand the nature of the contamination problem when dealing with alpha emitting material. Preparatory to the discussion of the specific instruments, a brief history of instrumentation is presented along with some "ground rules" relating to monitoring in the field.

HISTORY

It has been my opinion that the development of portable alpha instrumentation, through the days of the Manhattan Project and early in the life of the Atomic Energy Commission, lagged somewhat behind that of devices for beta-gamma measurement and detection. There were, indeed, small groups at various laboratories involved in the problem, but there was no great agreement as to the preferred technique. For this reason, to which must be added that of personal preference, there existed a variety of "boxes" almost exclusively based on the principles of the ion chamber or the air proportional probe. To a certain extent, this situation still exists today. Both principles admit to shortcomings when applied to the alpha problem. For one thing, ion chamber models lack the sensitivity required by operating personnel in controlling contamination satisfactorily. The air chambers suffer from environmental limitations, primarily the influence of changes in humidity. Weight and convenience in usage have been other common failings.

Interest in solving these various problem areas has taken an upswing in the last 3 to 7 years. One of the first advances may be thought of as wholly electronic in nature. This updated the circuits and components to take advantage of recent developments in these fields. Of particular importance to the individual instrument user is the fact that the weight of an air proportional device could thus be reduced more than one-third -- from 17 pounds to slightly more than 5 pounds -- to say nothing of the increased reliability experienced in controlled environment situations. There remained particular circumstances still in need of adequate instrumentation. One of these was for routine monitoring operations in a variety of environments and the other was for emergency or accident conditions. These were the two areas which fostered the design of the PAC-3G and PAC-1S, respectively. We will come back to this when considering each instrument in more detail.

SURFACE MONITORING LIMITATIONS

Portable alpha monitoring, at best, is a physically tiring and mentally frustrating endeavor. The essence of contamination assessment is to observe an instrument response in terms of activity per unit area (the active area of the probe) and relate this response to a possible airborne volume concentration which may be related further to a degree of hazard based on the best available biological information. The surface, itself, will materially affect an observation since an alpha particle is easily masked by its surroundings. Each step in this process, therefore, requires the exercise of human judgment and intelligence well beyond the capability of any single electronic instrument or group of such instruments. We must insert, also, into this train of events the fact that we are dealing with a material certainly classified as "more toxic than lead", to interject an industrial hygiene term. Plutonium-239, for example has an allowable body burden in the region of 0.5 microgram. This is the equivalent of one-37 micron particle.

Our limitation is then, basically, that monitoring efforts are those of contamination control as opposed to hazard evaluation. This control is the result of experienced personnel employing accepted good practices and instrumentation, tempered by individual judgment, so that more refined and after-the-fact determinations will not demonstrate absorption at or near the body burden level. The PAC-1S and PAC-3G can be useful tools in such a control program.

THE PAC-3G

Functionally, this instrument may be described as a "portable gas proportional alpha survey meter". It has been given the additional designation of IM-154/PDR-54 as the radiacmeter in the Radiac Set AN/PDR-54. The introduction of a counting gas, propane, into the probe overcomes the basic objections of an air proportional system while improving sensitivity and specificity for alpha detection. Background is quite low, being in the order of a few counts per minute. The entire probe assembly is comparatively inexpensive so that spares may be kept on hand to relieve conveniently window contamination or rupture problems. It will operate equally well in humid, dry or solvent vapor atmospheres. The short plateau of the air probe is lengthened to 200-250 volts, providing more stable and reliable data.

Limitations of the PAC3G are mostly of the nuisance variety. The logistics of gas supply is one. Not all transportation media can accept the gas cylinders and there has been some concern about the general availability of the cylinders at normal points of distribution within the DOD. Both of these points, transportation and availability, are improving.

The plateau is altitude dependent necessitating an awareness of this fact and the corrective action to institute. A shift of approximately 30 volts per 1000 feet change in altitude is involved. The shape of the instrument response vs. high voltage curve is not altered, rather a shift along the x-axis occurs which requires higher voltages for lower altitudes and vice versa. A continuously variable adjustment is mounted on the instrument panel to accomplish any high voltage alterations.

As mentioned before, the PAC-3G was designed for routine monitoring operations in a variety of environments. One of these environments was not the nuclear accident where extremes of temperature and very high levels of contamination could be encountered. The battery component was selected for long life at temperatures above 32°F, since most routine operations are conducted above freezing. Similarly, routine operations of contamination control over personnel and equipment demand detection sensitivity rather than the capability of measuring microgram amounts. Above 100,000 counts per minute there will be coincidence losses in the gas proportional system. One hundred thousand counts per minute relates roughly to one-third of the proper value for a probe of 60 cm² (the PAC-3G active probe area) at a contamination level of 1,000 micrograms per square meter, which is the Broken Arrow number of first significance. Shields which reduce the active probe area by one-third and one-twentieth are available when using the PAC-3G in this connection.

It might be useful to those of you who operate at some distance from maintenance and calibration facilities, to include a quick check list for periodic evaluation of your instrument. Of course, an understanding of the contents of the Technical Manual is assumed. Circuit and battery operation may be checked by pulsing a high voltage contact with an electrically insulated tool, such as a plastic-handle screwdriver. These contacts are at the probe end of the handle, the probe end of the cable, the cable connector on the case or the spring-loaded contact on the chassis. With the instrument turned ON to the X1 scale, these pulses will cause an upscale reading. Secondly, the gas supply should be checked by igniting a flame at the probe exhaust port. The height of the flame will indicate gas flow rates in the FLUSH and OPERATE positions. Lastly, the instrument should respond to an alpha source at a point close to the mid-voltage of the plateau which is that point where minor variations in high voltage, equally in either direction, do not result in major changes in instrument response.

THE PAC-1S

Functionally, this instrument may be described as a "portable scintillation type alpha survey meter". It has been given the additional designation of IM-170/PDR-60 as the radiacmeter in the Radiac Set

AN/PDR-60. The complete set, as supplied to most of you in the Air Force, consists of a carrying case, battery filling set, bottle of black lacquer for minor window repairs and spare face plate assemblies along with the PAC-1S, itself. Accessory items provided separately include a battery charger and set of Pu-239 calibration sources.

The temperature range of operation has been extended in the PAC-1S to -40°F by the use of the rechargeable wet cell battery pack. By going to the scintillation technique, the upper limit of instrument detection has been increased by a factor of 20 over the PAC-3G, that is, to 2,000,000 counts per minute. These two differences make the PAC-1S the instrument of choice in nuclear emergencies but do not obviate the need for an instrument such as the PAC-3G.

Problem areas, again, are in the nuisance category. If my visits to Air Force Bases on the west coast are any criteria, almost all difficulties involve the battery pack. Explicit instructions for filling, forming and charging are given in the Technical Manual and where these are carefully observed the batteries have stood up extremely well. Battery charger distribution has not followed instrument distribution exactly so that part of this problem arose early in the program but now is much improved. This battery pack and charger are not normally associated with radiacs necessitating a brief orientation of operating personnel to alert them of this difference and its effect on maintenance procedures.

As in the case of all alpha survey instruments, a thin window is required to give probe integrity yet not exclude alpha particles. This window is easily punctured. Minor punctures may be corrected by daubing black lacquer over the affected spot. The PAC-1S is supplied to you with spare face plate assemblies, also, to facilitate replacement in the field when several punctures have occurred and reduce the active probe area below some predetermined value. There is the other possibility that some of the crystals of the phosphor (ZnS) in the face plate may have eroded away or been abraded in handling to give a low response to a calibration source. If all other check points such as battery voltage, discriminator setting, probe efficiency, source strength and energy and calibration potentiometer controls indicate no malfunction, the replacement of the probe face is recommended. We have encountered this situation a few times in the PMEL here at McClellan AFB.

The PAC-1S will demonstrate a response to gamma radiation which is more sensitive than that of the PAC-3G. An awareness of this fact will preclude false reporting of alpha contamination in actual situations. Turning the probe over or backing away from the suspected surface will indicate whether gamma interference is involved. If it becomes necessary to perform an alpha survey with this interference, it may be either subtracted out from the total instrument response,

or electronically overcome by a change in the discriminator setting. In this latter event, the calibration for alpha detection will change, also, suggesting a determination of the magnitude of this change before proceeding with precise alpha monitoring.

Beyond the advantages of altitude independence, no warm-up time and the extended ranges in detection and temperature capabilities, one may find another useful feature. With the scintillation system, it is possible to adapt a variety of auxiliary and interchangeable probes for special applications. These will be listed in the next section in more detail.

The following foreshortened check list may be helpful to you for the PAC-1S. Determine the state of charge of the battery by hooking it to the special battery charger where available. Pulsing a high voltage contact as described for the PAC-XG will give a coarse check of electronics and of the battery voltage. Check the probe face for light leaks by exposing the active area to a light source, preferably, direct sunlight, with the instrument turned ON to the X1 scale. In the absence of such leaks, observe the meter response on the X1 scale. Adjust the discriminator potentiometer on the front panel so approximately 10 needle "kicks" per minute occur. This is a sensitive adjustment so avoid over-correcting. Finally, assure a response with an alpha source in a counting position. The plutonium clip source on the probe will read 9,000-14,000 counts per minute when placed against the protective grid network of the face plate.

ALPHA MONITORING ACCESSORIES

To familiarize you with instruments for special and limited applications, there is included a brief discussion of a Plutonium Wound Monitor, an Alpha Floor Monitor, a Plutonium Gamma Probe and a Filter Paper Probe.

There is a weak electromagnetic radiation associated with the disintegration scheme of plutonium-239 which may be useful. Plutonium lodged in breaks in the skin may be detected in situations when the alpha particles are masked by surrounding tissue, biological fluids or other interfering substances. It is not necessary to insert the probe into the wound to take advantage of this more penetrating radiation. A wound monitor based on this principle is available and is probably of interest mostly to medical personnel. Similarly, the principle may be applied in field monitoring when vegetation or inclement weather preclude detection by alpha monitoring. An interchangeable probe for the standard PAC-1S alpha probe may be substituted. Its sensitivity is considerably reduced over the alpha probe and interpretation of the instrument's response must include a careful consideration of other gamma emitters present either naturally or accidentally.

For large, flat areas, such as floors, streets, runways, or sidewalks, it is often more efficient, and certainly less tiring, to perform alpha monitoring with a floor monitor. The instrument for this purpose is basically the PAC-3G with a larger probe and wheel-mounted to permit more area to be covered faster with the operator in an upright position.

A very recent development has been a second interchangeable probe for the PAC-1S with a sample drawer and counting chamber to monitor the collection of alpha emitters on small filter paper samples, e.g., 1-inch diameter Whatman 41 or membrane filters. The standard PAC-1S probe can be used for this purpose but, with small samples, the probe face grid network masks an appreciable percentage of the total sample area. The new probe has no such interferences. Swipe samples or Samplair filters could be assayed in this probe, for example.

SUMMARY

A review of the two primary portable alpha survey instruments in the Air Force, the PAC-3G and PAC-1S, in terms of design and performance criteria, indicates that both fill a need in the total solution to problems of alpha contamination. Each requires a generous helping of intelligent human judgment for optimum effectiveness in a given situation. Each has been designed to meet a particular need but, with an understanding of the limitations, either may serve adequately under a variety of circumstances. Several auxiliary devices have been described briefly to broaden the picture of the tools available for control of most alpha contaminating events, whether of deliberate or accidental origin.

PANEL DISCUSSION

AVIATOR'S BREATHING OXYGEN

Moderator: Mr. John Bryant
Environmental Health Laboratory, Kelly AFB

Panel Members:

Mr. Joseph W. Fecke
Aeronautical Systems Division, Wright Patterson AFB Ohio

Colonel Cardis W. Bryan, USAF, MSC
Office of the Surgeon, Hq USAF, Washington DC

Mr. Clayton J. Osterhout
Naval Air Station, Alameda, Calif

MR. BRYANT:

We hope to be into our new facility about the first of the year, and we would certainly invite any of you to drop by and see it. We're proud of it, and I know that you will be, too. We in the Environmental Laboratories, especially we chemists who are not engineers, still feel that we are part of the team that Dr. Prince mentioned yesterday, and we are working to help you in doing your job.

We are going to try to hold this discussion on oxygen within the time allotted so that we can tour the Environmental Health Laboratory this afternoon. I'd like at this time to introduce to you the panel members.

First of all, Mr. Russell Phillips, a graduate of the Carnegie Institute of Technology, and who is now working at Middletown AMA and we'll let him discuss his job at Middletown later in the program. Second, Mr. Joseph Fecke, in the cryogenic liquid program, Engineering Aeronautical Systems Division at Wright-Patterson AFB. Our honored guest on the panel is Mr. John Osterhout, who in the past three years has been a real data-provider for us in the oxygen business. Mr. Osterhout is an Aeronautical Engineer graduate from the University of Washington. He is now with the Navy at Alameda Air Station as project engineer, power plant engineer, and materiel engineer. These are your panel members, and they are qualified to answer most questions relative to aviator's breathing oxygen. We hope to discuss with you the complete story on liquid oxygen as developed within the past five or six years in the Air Force. We are going to start off with Mr. Joseph Fecke who will discuss liquid oxygen plant operation, and what they are trying to do to clean up the process; then Mr. Osterhout will tell us about the analytical program they have been studying at the Alameda Air Station. After Mr. Osterhout, Mr. Phillips will tell you about the Air Force Procurement Specifications and how the Air Force is helping at this time to put a clean-up system into the LOX program, and we will then return to Mr. Fecke and ask him to explain the new purge kits that are being developed by the Air Force. We will let them carry the ball from there, and at the end of their discussion, they will have a few minutes for questions. We certainly want to keep this on as informal a basis as possible, so at this time we'll let Mr. Fecke tell us about the oxygen plants in general.

MR. JOSEPH FECKE:

First of all, there is a question of just what, exactly, liquid oxygen is. Liquid oxygen is a sort of pale, blue liquid, which at atmospheric pressure boils at -297° Fahrenheit. Liquid oxygen is normally obtained by liquefaction and subsequent fractional distillation of liquid air. There are a number of sources by which liquid oxygen can be contaminated. One source is the actual air which enters the plant in which it is to be liquefied. This air, of course, contains the oxygen, nitrogen, and other gases; it also contains carbon monoxide, depending on the location you are in. If you are in a highly industrialized area, there may be some industrial waste gases.

Another thing which may add contamination is the decontamination due to thermal cracking of the lubricants in the compressors within the plant itself. Another source is the filter system and other means within the plant to try to remove these contaminants, and of course, as long as we have humans operating these, they may not change the filters in proper sequence, or they may do an inefficient job of changing them. They may not clean the cartridge, which could permit some contamination to the LOX. Another source of contamination is actually a part of the inlet system, and this is the location of the plant, which has a bearing on how clean the air is which enters the plant. This has a direct bearing on the quality of the oxygen which comes out of the plant.

Now, there are several means of eliminating these contaminants which may be present in liquid oxygen. The first means is a filter system to pull out the dust, bits, and pieces from the inlet air to the generating plant. The second means is to remove the CO_2 , which is done by one of two methods; either by washing the air with a caustic solution, or by CO_2 absorbers in the liquid air line. The CO_2 absorbers consist of a filter which is approximately a ten micron filter, plus some chemical absorbers. In addition to removing the CO_2 , we have to remove the moisture. The moisture is removed by a combination of mechanical refrigeration and chemical dryers. There is another method which is used in plants which are located in industrialized areas to remove some of the hydrocarbons and things of this nature. Basically, this method is a bed of either silica gel or activated alumina which is in the product line, and which is maintained at liquid oxygen temperatures. This removes the majority of contaminants such as CO_2 , hydrocarbons, except the methane, that were not removed by the initial caustic wash. In order to remove the methane, a catalytic oxidation filter must be used. These catalytic oxidization filters convert the methane to CO_2 and water which are subsequently removed by the CO_2 and moisture removing systems.

The Air Force, by and large, does not have the same contamination problem with its generating plant that the commercial suppliers do because the Air Force plants are generally located at bases which are in more urban areas away from large industrial complexes. The commercial suppliers are usually located in industrial complexes in order to be close to their principal users. The liquid oxygen that we buy commercially must conform to specifications. The specification is MIL-027210, and until two years ago the only requirements for this oxygen were (1) 99.5% purity; (2) moisture which was .02 or less; (3) an odor test to determine if there was any odor in the oxygen, strictly a sniff test; (4) a carbon monoxide test.

About two years ago, the Navy started their work on oxygen analysis, and we in the Air Force started revising our specifications. In addition to the purity, the moisture, and CO and the odor, we added limits on trace contaminants. These trace contaminants are such things as CO₂, methane, acetylene, ethane, ethylene, nitrous oxide, halogenated hydrocarbons, and things of this nature. We have limited the allowable concentration of these particular commodities, in the case of CO₂, to 5 ppm; methane is 25; acetylene is .05, ethylene .2, ethane 2, etc. Basically, we are requiring a very low concentration of trace contaminants. Mr. Osterhout will now go into the analytical methods which are used to determine these concentrations.

COLONEL DILLS:

Could you elaborate as to the basis of these particular concentration values?

Answer:

These concentrations are based on several factors. First, as you know, all the values are well below any industrial hygiene values. The situation in which the pilot is involved is quite different from normal industrial situations, particularly in the case of a SAC pilot who may be on the oxygen as much as sixteen or eighteen hours continuously. He is also under severe stress, high altitude, and a lot of other things which enter into it, and when he's cruising up there, the least little amount of odor seems to be intensified, although on the ground it might not bother him at all. There have been occasions where people actually have become nauseated and upset because of foul odor.

Another thing is the fact that oxygen does not stay clean. You always have the oxygen continually being enriched in contaminants due to the fact that the oxygen is always boiling, and its boiling point is much lower than any of these contaminants, so as the

oxygen boils off it leaves these contaminants behind, thus continually enriching the remainder with contaminants. Therefore, if bulk LOX has even moderate concentrations to begin with, you will get build-up through your system in the storage tanks, storage carts, and the actual converter, so you have to have a safety factor from this standpoint. Another problem is the CO₂. We have limited this to 5 ppm because of the solubility of CO₂ in liquid oxygen, which is about 6 ppm. We would like to stay below the solubility limit if we can, because once you exceed the solubility limit, you have no guarantee whatsoever that the sample that you get is a representative sample, because you may have six inches of CO₂ laying on the bottom of the tank which you won't get in the sample.

COLONEL DILLS:

Can manufacturers do better than is required in the specification?

Answer:

Well, actually, we have been monitoring this program somewhat since about April or May of 1961 and by and large, the manufacturers are meeting this; some of the manufacturers are well below their maximums. One thing is interesting; I had suspected that increasing the quality control in the oxygen would reflect an increase in the cost of the oxygen itself, but the people at Middletown who buy this stuff tell me that there has been no appreciable increase in the cost of the oxygen itself, which surprised me.

COLONEL BRYAN:

Recently, we were reviewing military specifications, and I noticed that there was a difference in the contaminants allowable in the Air Force specifications and the Navy specifications. I also noticed that the use factor in the Navy operation was much more liberal than the Air Force use factor. Could you go into that, or had you planned to go into that later? I would like to add that two or three months ago we wrote a letter to AFLC recommending that they review this problem and find out why there was a variance, if the Air Force was a little too rigid, or the Navy was a little bit lax, recommending that the Air Force use the same allowable concentration in their procurement specifications and also possibly getting together on the use factor.

CAPTAIN WEINBERG:

The only comment that I can make is that from what I can find out, the Navy really has the only good set of data as far as build-up in the system is concerned. I haven't talked to Mr. Osterhout. I was waiting to hear his presentation with regard to whether their use limits were just what they found, so they accepted it. Our program on cryogenic sampling is going to get off the ground with a new sampler that is coming into the system, and I believe that at the present we have no good way of answering that question.

MR. BRYANT

Colonel Peterson suggested that the build-up in the transportation of liquid oxygen as it comes from the manufacturer is one concentrating element. In other words, the truck which brings the oxygen to the base would be the first concentrating vehicle; the storage tank would be the second. Colonel Peterson indicated that the Navy carries this on through about three more steps! The service cart and the converter would make it at least two more concentrating places. They stopped at the storage tank, because they didn't want to go to the converter and set a use limit on a converter, because this would mean that every time the aircraft was used, somebody would have to be checking the oxygen in the converter to see if it met the use limit specifications. A study is being undertaken to determine just what these build-ups are at the various stages as they go through from one settling to the other. In other words, if at the end of thirty days the storage tank build-up is found to be a certain point over the use limit, then the converter or the storage tank should be purged, and the same way with the service cart. If at the end of four weeks, we'll say, they find that the specifications are exceeded in the use limits in the service cart, then they will in turn purge the service cart every four weeks and on down the line with the same procedure for the converter. This would take, say, five days, and at the end of every five days the converter would be purged, so that there would really be no need to establish a use limit in the same magnitude that the Navy has established. These are things that Colonel Peterson and I were talking about yesterday, and when he comes in, I'd like for him to elaborate on this a little further.

COLONEL BRYAN:

In the case of the converter, if the Navy has a use limit of five and we have two, who is wrong? The use limit of five is not going to be detrimental to the pilot, because the Navy hasn't experienced any difficulty on that. Why purge all of these tanks and facilities unnecessarily if we can use a use limit of five down at this converter stage? If we purge our converter at two, we're wasting a lot of liquid oxygen.

ANSWER:

I'm going to let Mr. Osterhout comment on this.

MR. OSTERHOUT:

I'd like to develop some of our data before we answer some of these questions. They will be self-explanatory, I'm sure, and you can see where we are going, and why we have gone the road that we have. On this five times the new procurement limit, it appears that the people in higher positions are going to set that as the limiting factor on how much contamination we have in our aircraft. I personally, and a few other major Air Stations who have done a conscientious job of monitoring this thing, object very much. We want a three-factor on all of our ingredients as being a maximum acceptable for allowing oxygen to be used in aircraft. We have good reason to say so. At a number of our bases that each of us have been monitoring, we have found that we have had to get down to this three to keep them in the clear, namely in our area with the islands up in Washington. We've had consistent complaints on certain aircraft almost on every flight, and we were able to clean them up by getting down to the three use limit on the quality of our oxygen that is used in the aircraft. They are even working lower than three concentration now. They are down to one and one half. They do it by choice up there, and they have solved their problems, where two years and three years ago they were having complaints on every flight. Now, I'd like to develop my data here, and then you'll see some of the answers that will be of interest.

On December 12, 1956, we had an incident at the Naval Air Station at Alameda. A pilot flying at 20,000 feet in an airplane was overcome by sickness. His symptoms were nausea, lack of coordination, dizziness, and some other things that were later analyzed when he got on the ground. Fortunately he was able to get the aircraft back on the ground. His crew chief had to help him out of the airplane, and he was turned over to the medics, and on his discussion of his symptoms and their attempted analysis, there was great consternation. They said, "What happened to this man to make him so violently ill?"

We at Alameda did not have the first case of sickness. It was occurring at other places before December of 1956. However, we had the foresight to take some standard 514 cu. in. liquid oxygen cylinders, put a vacuum on them, take them out and open the regulator to a continuous flow in the cockpit, purging the lines. After we had the lines all purged out, we opened the valve in the bottle and took in a charge of about 70° PSI into our bottles. We did this all on the same day. The man got sick, and we had knowledge of prior incidents in this field, so we sent these bottles that we

took to Consolidated Electrodynamics in Pasadena for mass spectrometer analysis. Consolidated came back with unfavorable reports saying there was nothing in the oxygen above 50 ppm. They could monitor the 50 ppm, but they got no results. The test cost us \$300.00 and the flight of an airplane to Pasadena. We got the samples back, and we looked around to see what we would do with them, so we talked to the Air Pollution people. We sent the three bottles to Stanford Research Institute where they had been doing some work on air pollution. Using their infrared spectrophotometer, they were able to come up with some very crude numbers.

There were things in these samples of oxygen that were significant. For instance, they got three or four hundred parts per million of hydrocarbons. We couldn't tell what the hydrocarbons were, but using this favorable result, I spent about \$5,000.00 of Navy money the next few months sampling a lot of airplanes in the Navy area around Alameda, Moffett Field, Fallon, Crows Landing, and other places, and we collected quite a bit of data, using the Stanford instruments. We analyzed these data carefully, and concluded that we were developing a real significant case on what was in the oxygen that might be making people sick. In the spring of 1957, the Navy and the Air Force held a meeting in Washington D.C. with many of the manufacturers there, and they stated that the oxygen was as good as they could make it commercially. However, we were fortunate in having all of these data to present to them showing their trace impurities in our liquid oxygen and explaining that something should be done about it. We were, of course, exploring in the dark.

The Navy then gave me \$25,000.00 in 1957 and the fiscal year of 1958 with which I purchased an IR-4 infrared spectrophotometer from Beckman Instruments Division, and we set it up, using a 10 meter gas cell. We started in on detail analyses of everything we could get our hands on. In the meantime, we developed some samplers which I will tell you about in a few moments. I might say this oxygen problem has taken me half way around the world - from California to Beirut, Lebanon, and some of my people to Japan. We talked to a lot of pilots, medics, and we worked with other people. It's been a real interesting project.

Here is generally what happens in a liquid oxygen container, converter, trailer, storage tank, anything you want to name; even an oxygen system in an airplane. We apply time across the bottom of a graph and contamination and parts per million on the side of the graph. As a converter goes along bleeding off LOX, we hook the converter or the vehicle up to the infrared instrument and watch the contaminants come off. With time we see relatively small amounts come off until the container approaches emptiness. On any one constituent, we have a very large slug of impurity come off as that container goes dry, or approaches dryness. Now the

location of this peak varies with time a little bit, depending upon the boiling point of the particular constituent that we're talking about. Water would be the last thing to come off, CO₂ a little earlier, and methane would be one of the earliest to come off because it has a boiling point just above the boiling point of liquid oxygen. The first thing that comes off in large quantities in testing converter bleed-off would be a high volume of methane.

Now this phenomenon is going on in all your storage tanks. It goes on at the manufacturer's plant, and it results in contraction of impurities in their tanks. Most of us don't like to let our tanks go dry, because when we do, we introduce an atmosphere of air which results in the freezing out of CO₂ from this air, and this happens in all of our tanks, carts, etc. If moisture gets into any of these containers, we may get icing up of valves and regulators at a later date. So, in continuous operation, the Navy's policy is to keep LOX in the containers until they are periodically purged. That way you do not introduce atmospheric contaminants. However, each time we refill the container, the trace impurities stay behind, because they have higher boiling points than the liquid oxygen, and each time we fill the container, we bring in some more impurities which stay in the container. The boil-off rate on some of these containers is 20% per day just by natural boil-off, so in five days' time you have lost one full tank to boil-off. As you can see in noticing this phenomenon, you will pick up trace impurities with time. A normal new container full of oxygen will be very low in contaminants. These numbers that you see in your specifications, however, will change drastically if the vacuum is let off the tank. It would cause rapid evaporation of that tank, and instead of getting 25 ppm of methane, you probably would have a 1000 ppm of methane after thirty days, in the last parts of the tank as it goes dry.

COLONEL RAMOS:

Would you explain the reason for the line going down there to empty. Was it purged?

MR. OSTERHOUT:

No; something else will come along after this. It's just that methane is boiling off higher, and nitrous oxide may replace it in time, because it will boil at just a little higher temperature and come off in larger volumes at a little later time than the methane.

COLONEL RAMOS:

As that line goes down, it suggests to me that purging is not necessary.

MR. OSTERHOUT:

That is a possibility. However, we recommend purging. We find that it's necessary. You will leave behind water and a high CO₂ atmosphere if you do not purge.

COLONEL LIVERMORE:

Does that imply that all transfers from one container to another are made by going from liquid to gas back to liquid? Does it ever get transferred as a liquid?

MR. OSTERHOUT:

It's always transferred as a liquid.

COLONEL LIVERMORE:

Well, then, this implies that by this contaminant concentrating, it's been distilled, or fractional distillation is occurring. If it's transferred as a liquid, why does it concentrate?

MR. OSTERHOUT:

There is a natural boil-off in each tank, because they are vented to the atmosphere. Heat transfer into the tank causes evaporation.

COLONEL LIVERMORE:

So this is related to the length of time that it is stored as well as the transfer.

MR. OSTERHOUT:

Length of time it's stored is the factor that I'm trying to demonstrate here as the factor of collection of trace constituents in the container. This is just a boil-off picture as a container goes dry. Now this same thing enters into a converter system. A typical aircraft system looks like this; the pressure regulator valve, a heat exchanger, and a mask. Should you get liquid past this regulator, and it's very likely that we do, the valve closes and we evaporate to dryness all the liquid past this valve point, and as we are getting down to the last dregs of what's in here, we start getting trace slugs of impurities.

Another phenomenon on this thing is, as the liquid is moving downstream, the trace impurities stay in the liquid. As the demand of the pilot decreases, we start boiling off some of these things at this concentrating point. We have taken a so-called flash evaporator of not a very good design to put right at this point to

attempt to average out the peak concentrations that result from the closing of this valve, and the system functioning as a vacuum system eliminates this going dry, which gives the slugs of impurities. We have put a flash evaporator here of pretty large volume and found that we could drop N_2O from 400 ppm to 0.4 ppm. This is an example of poor design to put a big collecting pool at the evaporation site.

The opposite thing to do on this is to put in a real high intensity flash evaporator. We've put in an electrically operated flash evaporator in conjunction with some tests we ran from Bendix on a procurement specification for a tube flash evaporator design. We found that if we put 3000 watts of power in here, we could flash everything from -297° to near room temperature. When we put a heating exchange near here and flash from -297° clear up to room temperature or some controlled temperature instantaneously, we would not have any slugs of impurities coming down the system. There is a proposal for procuring this thing for aircraft, but the electrical people won't give us the 3000 watts in our airplanes as we've already asked. They are loaded electrically to the hilt, and putting in a heat exchanger would have a lot of additional weight in the airplane, and we haven't been able to convince them of its importance. Our quality control program has improved this situation so much that the people in procurement have figured there's no use adding this penalty on the aircraft system.

On this same subject again, back at the generating plant we see LOX coming out with trace impurities, any you want to name at this low level here. As we move to their plant storage tanks, we find that due to this boil-off rate going on continuously, they probably double the impurities in their liquid oxygen that they are going to sell. The same thing is going on in their delivery trucks. They are concentrating on their delivery trucks which probably give as much as three times of what it was when it was originally taken off the column. In our Navy storage tanks, delivery trailers, aircraft, and the converter, we have the concentration phenomenon going on, and as was explained earlier, the contamination level in the converter gains considerably as compared to the new oxygen produced back at the plant.

I want to talk a little bit about sampling. One of our methods of approach to this problem is to sample liquid oxygen. Our current method of sampling in the Navy is to take a 295 cubic inch cylinder, put in a little tube to hold a known amount of liquid (180 CC's), fill the tube full, and cap the container with a screw cap and valve. We put this cap on, the liquid converts into gas and expands into this cylinder and gives us a cylinder pressure of about 300 PSI. That is our current, classic method of sampling. I will describe an improved sampling device later. The sampling device just described is subject to collecting frost on the tube as we put in the oxygen, and the frost might

drop off into the container, giving us a high water reading or a high CO₂ reading. Very often this happens in careless sampling.

For methane, nitrous oxide and other impurities, we have very stable results as we can repeat one right after another, and we're satisfied with this sampler for several reasons. It costs us about \$70.00 a piece to make them. Some of the closed systems samplers that we have procured commercially have cost us as much as \$1000.00, and if we were to replace the 2,000 samplers over the world that we own, we would have a tremendous investment. So, we've been sticking with the cheaper sampler in our production sampling program for oxygen aboard ship, on land bases, and where have you. I've just described filling the sampler from a delivery trailer or an aircraft trailer.

To get a sample on an airplane, we take a standard connection, hook up to the converter, put the converter on build-up, and we'll get LOX flowing back out in a stream. We put on some tubing, pour it in the bottles, and when the bottle is full, we cap it up, and we've got a sample that we have taken from the airplane. Each airplane is different: sometimes we have troubles, but I've not seen a Navy airplane that we can't take a sample from.

The trace contaminant problem may resemble the following pattern in normal air. We probably have around 300 ppm of CO₂ in a smoggy city, 2 ppm of methane, 1/2 ppm of N₂O, 0.1 ppm of C₃ plus C₄ hydrocarbons, and you are unable to see these other things that we often see in oxygen in normal sampling of the atmosphere with the kind of equipment that we are using. We've seen samples that run from 50 ppm to 400 ppm of CO₂ and I might say that, by refinement of our sampling devices, the figure has been greatly reduced. We have actually seen methane up to 400 ppm in samples from airplanes. However, in our system of sampling now, we seldom see anything over 100 ppm, and only with those people who are doing poor housekeeping will we see oxygen with 100 ppm of methane; N₂O, 0 to 5 ppm, but we've had one producer in the Hawaiian Islands who delivered oxygen to us with 2500 ppm of nitrous oxide in it. He did get a contract after he cleaned up his plant, and we are practicing good quality control with him. On C₃+hydrocarbons, 0 to 5 and on C₃+hydrocarbons, 0 to 5, and on C₃+ we have our troubles.

Unless there are a lot of these things present, we can't tell which hydrocarbons they are. We've seen concentrations from 0 to 50 ppm of acetylene, the hydrocarbon that will blow up an oxygen plant. The producers say that when acetylene goes over 2 ppm, they are apt to have an explosion in their plant, because it collects where it will react with oxygen. They are very careful on this point; however, once in a while we do find a plant in

which their purifying equivalent becomes saturated while they are trying to get a change made. Ethylene has been found from 0 to 50, and ethane from 0 to 5 ppm.

Very interesting contaminants are halogens. Very often some very large plants in the bay area who have a Freon refrigerating system for cooling the compressed air, have leaks in their compressing systems, and these leaks will go right over into the stream of air that's being compressed. This is very often the cause of complaints. We have one base down at Guantanamo Bay, Cuba, where a Navy-owned portable plant had a Freon refrigerating system. Consistently, month in and month out, we had odor complaints from pilots who used LOX from there, and our analyses showed consistently that there was a Freon leak in their systems. This is one very good area in which that instrumentation is doing the job for us. It's going to have the capability to locate these leaks in the process of their systems, even when these leaks are very minute - 1 ppm in the order of which may accumulate and give trouble.

A local producer of LOX in the Bay Area was having trouble putting a new plant on the line, and it took him about three months to locate and correct his trouble. He had not used helium leak detection to check out his compressing system for Freon leaks, and as a result, they were dumping Freon into the oxygen that we were buying. In our work with them we found that the discharge point from the compressing system which contained the refrigeration material was about 50 or 75 feet from the air intake for the plant, so Freons were being discharged into the atmosphere and thrown right back into the compressor. The producer stated to me that it was costing him \$2,200.00 a month to buy replacement Freon for this plant. He was making and selling oxygen to us, but we cleared our troubles there at Moffett Field by cancelling his contract. We had about three months of odor complaints at Moffett Field from this one source.

Our samplers concentrate impurities, and our Military specification is geared to the sampler described earlier. Our numbers of acceptance of the product are almost identical with yours; i. e., 25 ppm methane, 0.05 ppm acetylene, etc. However, the concentrating effect of a sampler is very important. If you are going to use our limits, you may also be very interested in the sampler. The sampler I will talk about is called the Cosmodyne sampler, and it concentrates approximately half as much as does our sampling device. When we are ready to sample, we pass LOX in across the top and around the cup to precool it to liquid oxygen temperature. If we didn't do that, as soon as the liquid hit this relatively warm cup, it would flash into a gas, and we would not have any liquid trapped in the cup. This would present a sample that would have a very uncertain analysis.

° The current method of sampling with the Cosmodyne is to pass liquid over the cup as described until a nice, steady stream of liquid oxygen evolves at the outlet. We then open the valve to allow LOX into the cup which was cooled to LOX temperature by passing the liquid over the top as described. We catch a full cup of liquid, close the valve, and we've got a sample. The LOX in the precooled cup expands into the large chamber, and you might ask, "Well, why, when you sample like this, doesn't the liquid pour over into the inner jacket?" A pressure differential prevents the LOX from entering into the closed trap. When liquid oxygen evaporates, it expands 860 times; so if you ever trap liquid oxygen in a closed container with no expansion space, you will very likely have a serious explosion. We control this by filling the cup with LOX and leaving a little expansion room. You ask, "Why don't we fill this, too?" If LOX starts spilling over, it hits the warm outer container and immediately flashes to a gas, creating a gas pressure in that compartment, and the gas pressure prevents any flow of liquid out of the cup, because of the pressure difference. It is vented to the atmosphere through the whole system.

An Air Force sampler was developed at WADC consisting of a little steel chamber device with regulator valves. It also employs a cup which is filled with a one-unit quantity of liquid oxygen by flow-through, by opening the valve and just letting it flow and discharge upward. When a steady stream of LOX is flowing out of the outlet, the two valves are closed, and this one unit quantity of liquid oxygen is allowed to expand into the container, resulting in a good sample of liquid oxygen that can be analyzed as a gas. You might ask why we want to catch it in unit quantity of liquid oxygen in any closed container. We found that if we try to analyze the gas coming off of a pot of liquid oxygen, it will be almost 100% pure, because the impurities are staying behind. They have a higher boiling temperature than liquid oxygen, and only the liquid oxygen will come off until such time as all the oxygen is gone, or close to it, and then the impurities will come off. So, in order to see what's in the oxygen, we have to trap a unit quantity of the liquid and average out by evaporation of that unit quantity to see what's in it.

The Cosmodyne sampler considered for use by the Air Force does not concentrate as much as our Navy sampler, which would indicate that the Air Force Procurement specifications should be very carefully reviewed. I notice now that you are accepting oxygen at the limit that the Navy does, and that means that your acceptance limit on trace impurities will be twice what ours are, because your sampler concentrates half as much as ours does, so if you are to go up to our limits, you would have a sample with twice the impurities in it that ours does. Our sampler, which is very crude and cheap, has got quite a spread in the normal curve as compared with the Cosmodyne, which is more accurate. However, for our purposes, and

the price that we are paying for it, we feel that we are doing all right.

When we get a concentration of a contaminant around 40 ppm with our sampler, we will get approximately half that reading with the Cosmodyne samplers, so when we use the Cosmodyne sampler, we've got to take the Cosmodyne numbers and multiply by 1.73 in order to get the correct number that we can interpret in our specifications. This is based on probably 100 to 150 test samples that were taken both by the Navy and the Air Force people. We sampled and analyzed liquid oxygen from the Air Force here in Sacramento, the SAC Command, and at Travis for approximately nine months. They used our early Cosmodyne samplers and a correction curve was established for this sampler.

There is a disadvantage when we go into too good a sampler. Our instrument detectability is around 1 ppm, and if we have anything less than 1 ppm, we aren't going to see it, so if I have a sample with 2 ppm from our C-276 sampler, and we analyze it, and with the sampler I bought from Cosmodyne, there's a tendency that we've run ourselves out of business, because we have not concentrated enough contaminants to see what the impurities are with the infrared spectrophotometer. Again I would suggest that you review your specification limits if you are going to use the Cosmodyne sampler and possibly interpret or crank in a correctional factor if you are trying to line up with the Navy.

I want to talk a little bit about improved instrumentation. We say we can see in the order of 1 ppm of impurities by infrared analysis. A typical IR analysis would give us something like this: methane 26, CO₂ 41, N₂O 21 ppm, and nothing down below. Infrared is not good for water; CO₂ values are not too accurate using our sampler. However, for anybody that has high CO₂ in their generating plant, it will freeze it up, so we are not going to worry about the CO₂ if we should get CO₂ values in any sampler. Methane and the other things are the things that we look at.

Now, to explore a little further, we have had cases where the pilot complains of odors that our analysis does not explain. Our nose works down to probably 1 part per 20 billion for certain kinds of impurities, and our detectability in instrumentation is 1 ppm, so we are on the search at Alameda for parts-per-billion detectability. We have now at Alameda two flame ionization gas chromatographs which can see things in the same sample that we missed with IR. For example, 16 parts per billion of ethylene, 21 parts per billion of isobutane, etc. This flame ionization device is good basically only for hydrocarbons, but it gives you an indication of the direction we are going.

We have also done some work on ozone in our LOX studies. We have never seen ozone in any production use of liquid oxygen or in any of our airplanes. I took a 50-gallon trailer one time, and let it go completely to dryness. As it went to dryness, we got 0.3 part per billion kick out of the ozone indicator, but this was not worth discussing. It's not in the range where it could cause trouble, and it was representative of a lot of concentrating that had gone on in that trailer. We never expected the ozone to be significant.

Another device that we have used is the Titrolog instrument, but it has not given us any data. Another device is the mass spectrometer with which we've not done very well. One of our problems with this instrument is the limit of detectability which is normally about 50 ppm. Our nose works much lower than that on many contaminants. We have tried to concentrate below this 50 ppm limit for the mass spectrometer by freeze-out. Freeze-out does not work because of the limit of solubility of the constituents in the oxygen. We can't freeze them out if they are below the limit of solubility. We have done some work on concentrating with the molecular sieve filtering device by heating it up and boiling it off into the mass spectrometer, but we have very little good information to date.

I want to say a little bit as I close on medical tests done on patients breathing oxygen with a large number of impurities. Dr. Bartlett at Pensacola Naval Air Station ran all these tests after we mixed the impurities. The following are some of the data that came out of this program. Six Naval aviators who were very interested in this subject breathed N_2O at 130 ppm and came up with only guessing accuracy on whether they were getting a contaminated product. Also, in differentiating between pure oxygen and the contaminated oxygen, giving them 130 ppm of N_2O , we also had only guessing accuracy. When we raised the quantity of N_2O to 1450 ppm, four out of six of these fellows had a pretty good effectiveness in saying they were getting something that they didn't like. We made up samples containing 9 ppm ethylene, which is one of our suggested candidates for trouble, but we made only enough samples to test three individuals with this contaminant. One out of the three was effective and consistent in saying that this was contaminated, and he could tell which sample was pure and which one was impure. The other two pilots gave nothing better than guessing accuracy on these samples. We then raised the concentration of ethylene to 110 ppm, and all three pilots gave only guessing accuracy.

I don't know the explanation for this. On a mixture of contaminants, five subjects out of six consistently guessed wrong, and the pilot's tendency was that they liked their oxygen with a

few of these contaminants in it. If they had their choice of saying which one they liked, they liked the one with a small amount of ethylene or other impurities in it. In the case of ethylene, at 110 ppm, the trend was completely reversed. They actually accepted the contaminated oxygen and rejected the pure oxygen, in the case of ethylene. Using methane at 420 ppm, we had one man that was 100% of the time just opposite where he should have been. The other five pilots gave guessing accuracy. This was all done statistically, and I don't want to get into the statistics of this thing, but I can review what happened. Essentially, results were obtained on differentiation of the samples with methane at 80 ppm. They were all guessing.

Another very confusing aspect of our tests was, when we gave them two bottles of oxygen from different manufacturers, they could consistently differentiate accurately between the sources of the two bottles of oxygen. We don't know what the difference was. We couldn't analyze it because it was way below our instrument detectability, which indicates that we have got to go further in our capabilities. On our continuous testing, we gave them some isobutane at 9 ppm, and their accuracy was guessing. This is where we interrupted the test sequence and tried to fool them by not trying the two samples together, and again they were only guessing. With isobutane at 40 ppm, they were 90% accurate; with ethane at 7 ppm, one man was 100% right all the time, and the others were guessing. This one man consistently had a better nose than everybody in the business, all through the test program. He could pick out things consistently, and it's the same man who was right on the mixture; it's also the man who was 100% opposite on the methane experiment. On the last test, we slugged these fellows with methyl mercaptan of 20 ppm, not very much, and their answer was that we had literally knocked the tops of their heads off. 20 ppm of methyl mercaptan is below our limit of detectability by infrared. 70 ppm is the lowest we can see, and should we ever have a methyl mercaptan in our oxygen, we have trouble.

What do all these things mean? The Navy is training their pilots right now to detect these odors. We are using N_2O , ethylene, methane, acetylene, and these limits are not given as absolute values for whether they will make a man sick or not, but for use as indicators for the manufacturers to purify their products adequately. Some day when we have better instrumentation, we will be talking about more positive values. We've seen people come in from flying with methane much higher than the 25 that's allowed. I think SAC's handbook allows 10,000 ppm of methane for an eight-hour working day, so you can see we are nowhere near the threshold of making a man sick. But we are using these numbers as an acceptance criterion; as an indicator of whether the man producing the oxygen has done a good job, whether the maintenance

people have maintained their equivalent adequately.

On these investigation problems that I have made of pilot sickness, there has been a breakdown in our chain of LOX transfers. The trailers have had no vacuums, invariably, when the people are consistently getting sick. On one investigation, three out of the four trailers had no vacuums, and they were concentrating oxygen at the rate of, probably, two, three, four hundred per cent per day instead of the normal rate of five percent per day. With this high boil-off process going on, these impurities were concentrating very rapidly. There was no wonder that the pilots were getting sick, because the impurities were building up to very high levels in their containers.

Another thing we found in this business is that people who purge their equipment periodically are not having trouble. We have had lots of complaints, though, from people that have poor vacuums on their trailers or poor maintenance. If the trailer hasn't been in for overhaul for from two to five years, none of the vacuum gauges work on the equipment, and the boys are careless. Usually our troubles come from these areas. Sampling has been a big factor also. We will say we have screened out the producers of bad oxygen. We find some of our problem areas aboard ship. They do use Freon refrigeration in the ship's air-conditioning, and very often the ship will be dumping Freon into their compressors, and pilots will be complaining repeatedly. If any one has a question, I will try to answer it.

QUESTION:

I wonder if it's necessary to strive for greater detectability. I think our pilots need more education in that if oxygen samples do smell a little bit, it doesn't necessarily mean that it's going to kill him.

ANSWER:

That is true. They have never found anything in our oxygen that will kill a man.

QUESTION:

I am not saying that you haven't found things that won't make them sick, but I think we should strive at a level which is below that which will make him sick, or a level which, for mechanical reasons, like freezing out of CO₂ in the lines, where there is a dangerous hazard. I think we are striving at ultra, ultra purity which is expensive. Our detectable means are being pushed to their limits, and I wonder if it's necessary?

ANSWER:

We have placed through the world about twelve infrared instruments at a cost of about \$20,000.00 each. We are aiming in a direction of putting some of the samplers at every Air Station and aboard every carrier. We now have a turn-around time on our samplers, sometimes as high as forty-five days. In some cases the oxygen is long gone by the time they receive the report. It is essential that they get good oxygen. This is why we are going on with the program of developing the use of flame ionization detectors. We hope to be in business with an instrument for around \$1,000.00 when it is refined.

QUESTION:

What kind of flame ionization do you use? Is it a Beckman instrument?

ANSWER:

We are using a Beckman; and we also have a "Hi-Fi" by Wilkins Instruments.

QUESTION:

In the case of N_2O , one can breathe very high quantities and most people will agree that it's there, as is shown in your statistics, but I question the concern over these gases that you mention at the limits that you are concerned with in the specifications.

ANSWER:

If we had better instrumentation, we'd certainly lower these indicators, because they are not things that would normally make the men violently ill. We would probably be working with mercaptan or something like that which would be more apt to cause pilot sickness. Any one of two hundred fifty thousand organic compounds could possibly make a man sick, and I can't conceive of us ever having a calibration curve on each one of these 250,000 organic compounds. Any one of these 250,000 organic compounds might be in our oxygen, some day, at some place, and under some circumstances, and we just wouldn't have any capability for that many types of materials. We do think that their business will go along with using the indicators of the cleanliness of the oxygen, but I cannot say whether it will stay at this parts per million level or go down to parts per billion where you have no capability. If we have parts per billion detectability, I predict we will go there.

QUESTION:

Wouldn't the cost of oxygen and instrumentation then increase?

ANSWER:

Not necessarily. In some cases, the manufacturers had to move their plants away from the mud flats. At one of our bases the oxygen plant is right at the end of the warm-up strip at the end of the runway. All day long aircraft are warming up and discharging their fumes into the air intake of the generating plant. At night, the on-shore breezes bring in the winds off of a tropical swamp and into our plant all night long. We've taken this plant and moved it to a high promontory overlooking the nice, wide ocean, and we have not had any more trouble with that particular plant.

MR. R. E. PHILLIPS:

The Middletown Air Materiel Area has two functions in this program. One of them is to procure the aviator's breathing oxygen in accordance with procurement data supplied by the Aeronautical Systems Division. The second function is to provide the instructions to our customers who are, of course, the using organizations. I feel very much in the middle, and I think it's appropriate that our AMA is named "Middletown." Actually, that name came about because the Middletown Air Materiel Area is at Olmstead AFB, which is adjacent to Middletown, Pa.

It's a little hard to figure out why it's called Middletown now, but it's not hard for me to figure out why we have a Middletown Air Materiel Area. We are the swinghorse in this famous team that was keynoted a couple of days ago. We do pull our share of the load, and we follow the Aeronautical Systems Division, and I guess the Navy, because of the amount of work they have done in this field is also one of our lead horses. We get satisfaction out of pulling our share of the load, but we sometimes get a little tired of our view!

The procurement of the liquid aviator's breathing oxygen has not been difficult. The industry has been able to manufacture liquid oxygen to the required specifications. We have had a few instances where the periodic sample submitted to our laboratories has failed the trace contaminant requirements of the specifications. In every case it failed so miserably that it was obvious that somebody did not clean their sampler properly, and the manufacturer went out of his way, of course, to clean his sampler the next time and pass the test satisfactorily. In the gaseous breathing oxygen, we've had considerably more difficulty. In the beginning, about one half of the samples

sent in were failing the periodic test.

I'm emphasizing the periodic test because although there was a pre-production test, we were not able to get a continuous flow of product into the using units if we insisted on the pre-production tests, so until April we had to waive all pre-production and periodic samples. But beginning on the first of April, every contractor supplying the Air Force has been required to send in his periodic sample, and this has been a hardship in the gaseous oxygen field. The principal contaminant was nitrous oxide. Some acetylene and some carbon dioxide were found.

We feel that we have gotten excellent cooperation from industry in putting these new specifications into effect. In the last three years we have asked industry to supply aviator's breathing oxygen to three different specifications, all with significant changes in them, so it's been a rough adjustment for industry to get in line. As far as the price goes, when they put in their bid this past year, I don't think they realized what they were going to have to do to meet the specification. Probably they had always supplied the Air Force with aviator's breathing oxygen, and bid their usual price. I imagine there may be a change in price next year when they realize the trouble they have to go to. Instructions to the customer have been difficult for us. The headquarters of the major commands are continually insisting on more controls. Very often we find when we put instructions requiring more controls, the operating units come in and complain about the additional delays and the additional efforts that have to be made and additional waste of products. It even involves the cancellation of missions.

The surveillance program that is being conducted at the present time will iron out a considerable amount of the difficulties. The last two years have been a transition period of rapid changes. The Air Force, somewhat belatedly, has realized the extent of the problem in connection with Mr. Osterhout's efforts, and we are catching up very rapidly. The surveillance program at present has been limited to fourteen selected bases. This was because we had enough samplers to service fourteen bases. I'll go over very rapidly the results and answer any specific questions in the discussion. In our first round, we covered ten bases out of a selected fourteen bases. Six bases had liquid oxygen in the storage tanks that exceeded their use limits. Four had oxygen within the use limits. On the second round we managed to correct two of the six bad ones, leaving four bases which exceed their usable limit. The peculiar thing is that there have been no incidents affecting flying personnel in all this time. This does not prove the absence of a potential hazard. We are

planning to expand the surveillance program to every Air Force Base using aviator's breathing oxygen. The four petroleum and chemical laboratories under the AMA supervision are equipped now to conduct analyses for trace contaminants. We are presently receiving delivery on five hundred Cosmodyne samplers which will be distributed directly to the bases concerned. The purging units which Mr. Fecke will describe are on procurement, but delivery is not expected until May of 1962. At that time we will be able to detect the location of our contaminants, completely purge the storage containers, and start with fresh aviator's breathing oxygen. The surveillance program at the present time indicates that the operation of the one-ton generators at Air Force Bases leave something to be desired.

MR. JOSEPH FECKE:

I would like to talk about the purging units we are in the process of procuring, which will be used to clean oxygen and servicing equipment when it becomes contaminated. Basically, they are both electric heaters. The type used for tanks uses an ambient air blower, either a centrifugal or positive placement type. The air flow is set at 60 cfm with a pressure of about 5 PSIG at a temperature of 350°C. The air is then flowed through the tank until the temperature of the air leaving the tank is approximately 300°C. We feel that this will get rid of the moisture and any of the other contaminants that have been deposited within the tank during its use period.

The converter purge kit, instead of a blower, uses a gaseous oxygen source - normally, from a six-bottle cart. The temperature of the gaseous oxygen which has a pressure of 50 PSIG out of the gaseous trailer is 235°C. The heater is basically a pressure regulator with an electric heater with thermostat. We use this heated oxygen at a flow-rate of 65 liters to warm the converter itself and to remove moisture and other contaminants from the converter. At the present time, we feel that a purge time of ten minutes per liter capacity plus one hour will be sufficient to remove the contaminants from the converter.

MR. BRYANT:

I would like to say a few remarks about the liquid oxygen business as it applies to us. In the first place, I think we should remember that we in the Medics are not in the quality control business, but we are in the business of trying to see that our men have the best oxygen, and for that matter the best of anything that we can give them, even if it costs more.

I see Colonel Peterson has arrived, and would at this time like to ask him if he will answer the questions Colonel Bryan presented concerning the difference between the use limit employed by the Navy as compared to the Air Force's limits.

COLONEL PETERSON:

I can't really answer this question directly, because I don't know why we've established use limits at all. I do not know how the Navy use limit of five times procurement became established. The purpose of considering the problem of oxygen contamination from a medical point of view is to assure us that our pilots are not going to become ill, and that we're not going to have medical incidents as a result of using contaminated oxygen. I wholeheartedly agree with quality control measures in the procurement of oxygen. We also should establish definite criteria. I have no particular objection to the present limits that have been established. I'm not sure that I wouldn't prefer a limit of contaminants somewhat less than those that have been established.

Concerning the use limits, however, the only practical value I see is that it gives us some indication as to when we should purge the storage tank, the oxygen cart, or the converter. Rather than attempting to establish a use limit arbitrarily, I believe that it would be wiser to study the build-up of contaminants within the storage tanks and all the other tankage systems between production or procurement and actual in-flight use. Using oxygen of a known purity, we should study build-up of contaminants relevant to the quantity of oxygen passing through these tanks. Then we can better decide when a tank should be purged from the quantity of oxygen going through the storage systems rather than trying to guess at what point we must purge. Another alternative is to determine analytically when purging is necessary. The problem of this is that it automatically generates the requirement to have a laboratory facility at every base. The feasibility of this is questionable.

We at AFIC have tentatively decided to determine the concentration of contaminants in our procured oxygen and to study the build-up level of these contaminants through the various tankage systems in terms of quantity of oxygen used. Based upon this information, we will establish a time-use criterion for purging. I think this will eliminate to a large degree the need for doing analytical work at the individual bases. Based upon present information, we feel that this approach is the most practical and economical.

MR. OSTERHOUT:

The five-factor limit was the result of an operation conducted by the Marines on an island off the coast of California. A record was kept of every gallon of oxygen generated in portable generators. It was determined that we made five times as much oxygen as we actually have used at the pilot level. I personally favor the three-factor because we know that we need it to keep a number of our bases out of trouble. Currently, our policy is this. We do not monitor aircraft; we do not monitor trailers or storage tanks; we don't have the instrumentation. Primarily, we monitor the oxygen when procured and also monitor some stations. Aircraft are purged every two weeks. Our storage trailers are purged approximately every two months. Purging of the station storage tanks is accomplished about once a year. If they are high utilization units, the time between purges could be extended when squadrons have a few airplanes and only one trailer and perhaps purchase one trailer-load a month. These groups were consistently in trouble. They were not purging the systems frequently enough.

QUESTION:

We are all, as Professor Hatch said, in love with our instruments. We do have the odor test which is described in specifications. It is now in the TO 42B6-1-1. This test is highly sensitive. There are no instruments that will compare with the odor tests to detect certain types of contamination, and there is much evidence to suggest that there is no one specific dangerous type of contamination. Generally bearing materials are present when contamination occurs.

DR. ASHE:

Do any of you gentlemen know whether or not any tests have been made on human subjects about odor detectability on the ground versus at about 100% oxygen above 30,000 feet. Is there a difference?

COLONEL BOYSEN:

I'm not aware of it.

SANITARY ENGINEERING PROBLEMS IN FORWARD AREAS

Lt. Col. John Pierce, MSC
Assistant for Life Sciences
Deputy Inspector General for Safety
Norton AFB, Calif.

In this period of missiles with their exotic fuels and nuclear devices with their attendant complex problems, this subject may not appear very interesting and glamorous, but I dare say that it is of equal or greater importance than some of our problems in the other areas. We've heard about many fuels, radiation problems, and industrial hygiene problems, and these are complex, they are new and they are interesting, and this subject that I'm going to speak on may sound like bringing a ham sandwich to a banquet, but I daresay that it's probably as important as anything you'll ever run into.

My personal experience with Forward Areas has been, to say the least, quite limited and of a secondhand nature. In the last three years, however, there have been two fairly major operations in the European Theater that we were concerned with. One of these was the Lebanon operation at Beirut, and the other was the airlift of the United Nations troops to the Belgian Congo. During this latter case, my only contact was by single side band radio with the flight surgeon of the 322nd Air Division, who was actually on the scene and responsible for the health of the Air Force people there. I'll talk about Lebanon first and then the former Belgian Congo.

Now the little Air Force Base at Incirlik, Turkey, which is a small village about seven miles from Adana, Turkey, had in 1958 a base population of about 2500 people - and this included dependents, dogs, cats and all. The water supply was furnished by three drilled wells, with standard Corps of Engineers pumping, storage and distribution equipment. The best well had a yield of about 125 gallons of water a minute, another one had about a 50 gallon per minute yield, and the third one was not in use. (I think these figures are right; I'm quoting from memory.) The daily consumption was in the order of magnitude of around 200,000 to 250,000 gallons a day, depending on the season.

Now this, roughly, was the situation that had existed when the Air Force was directed to airlift troops of the United States Army to Lebanon. Incirlik Air Base was in a pretty strategic location, and it was to be the advance staging and refuelling area for the Army troops and aircraft. And as aircraft personnel and equipment began

to hit this small air base, the population exploded overnight almost to around ten to twelve thousand people, and the situation with regard to the water there got real critical. On the second day they resorted to water rationing, but the static level of these two wells fell steadily. The Air Force Commander down there was advised that the wells in all probability would fail and it was recommended that they airlift in some four-inch invasion type pipelines to tap an unused well in the city of Adana, about seven miles away, which was a real good source. It was decided, though, to rely on the existing wells, because the airlift capacity was needed for more critical items. Two days later, these wells did fail completely, and this decision was reversed. I have no quarrel whatever with this commander's decision. He did have water and he did have a very critical need for the airlift. He was in a bind and probably if you had been in his shoes you might have taken the same calculated risk, and I don't quarrel with this at all. So he said, "Well, we won't do it, and if the wells fail then we'll airlift in the material." And that's what happened.

When these wells failed completely, the nearest source of water was an irrigation ditch about three miles from the base. This water was free from turbidity, but it was a bacteriological nightmare, because this irrigation ditch passed through a Turkish rural area and was used for everything from bathing to disposing of dead animals. The bacteriologist from the 4th Epidemiological Flight who was up there, almost cried when he looked at his test tubes and membrane filters. He was pretty shook at this water, but it was wet and it was the only thing around there.

We flew in a Corps of Engineers Water Company from Frankfurt. They had a standard 50-gallon-per-minute water purification set, and they went into business on the banks of this canal. Now, I take my hat off to these boys. They had been trained at the Corps of Engineers School at Fort Belvoir, Virginia, and they knew what they were doing. They set up their equipment and they went into operation within about eight hours from the time they got off the aircraft at the Air Base. We pre-chlorinated this raw water from the canal at a dose rate of 20 parts per million; then it was coagulated, settled, and pumped through the diatomaceous earth filter and re-chlorinated to a free residual of 10 parts per million. The entire output of this unit was hauled by a water truck to the base where it was transferred to the ground storage reservoir. This was a batch-type operation, but they produced enough water for all drinking and culinary purposes, and we had enough water available for flushing the toilets in the barracks twice a day and enough water to shave with, but of course the showers and things were turned off. This operation lasted about a week or ten days.

Meanwhile, back at the ranch at Headquarters USAFE, action was taken to procure and airlift in a deep-well turbine pump and fourteen miles of four-inch invasion type pipeline. If you are not familiar with this line, it is of very thin steel, not much thicker than a stovepipe, and it's wrapped, but it's light and it's easy to put together. We used this equipment to pump water from the good well at Adana to the base at Incirlik. We put two four-inch lines down the railroad right-of-way into the base. The loss of head in seven miles of four-inch line is considerable, so we had to put in a gasoline-driven booster pump about half way between the base and well field.

Then we chlorinated it at the entrance to the base reservoir. This solved the water supply problem during the remainder of the Lebanon airlift, which fortunately didn't last much longer. Incidentally, this four-inch line, which has a normal life of one year, is still in operation. The wells have been rehabilitated and are now able to produce at their rated capacity.

There is a military construction project which has been funded to build a sixteen-inch cast iron line from Adana to Incirlik, but they are having right-of-way difficulties with the Turkish railroad people who intend to double-track this railroad center later, and they don't know where to let us put our pipeline.

Now, during the entire time in Turkey, the water supply was the most difficult problem, but in talks with Army personnel they tell me that in Lebanon their worst sanitary problem was fly control. And let me tell you that some of these Middle Eastern fly populations you would have to see to believe. When I first heard the following story, I thought it was funny, but the more I think about it, I think maybe it might be valid. At any rate, at one place where an Army Company was stationed, their little Epidemiological Team was sent in to spray this area for fly control, and the men in there said, "Don't kill these flies; stay the hell out of here; these are our own flies and we're accustomed to them. If you kill these flies, all of the flies from the native area will swarm in on us!" Now, I don't know how much validity there is to this. At any rate, this was told to me by the Company Commander, and I think it's a true story. It may not be, but it sounds good. Maybe some of the epidemiologists in the crowd can probably tell me if this Commander was right. They made extensive use of insecticides, but fly-borne dysentery outbreaks were very prevalent among the army troops, and it was only partly controlled.

Our participation in the airlift of United Nations troops to the Belgian Congo and the evacuation of Belgian civilians was confined to air crews and communications personnel of the 322nd Air Division, with headquarters at Evreux, France. Now here again the major problem was water; and in addition to that, malaria was endemic in the Leopoldville area.

The first thing that happened was the breakdown of the water purification plant, and naturally the Belgians quit their anopheles control measures, and this posed a real hazard to those air crews. The crews were housed in a hangar at the Leopoldville airport, and for a few weeks their fluid requirements were met by cokes and beer and water that they brought with them on the air trip.

Our headquarters had made arrangements to ship in a water purification set and a crew of preventive medicine technicians to operate it, when we were notified that the local water treatment plant was back in operation, so we didn't move. The air crews communications personnel were using mosquito nets in the hangar; they were taking malaria suppressive drugs, but in spite of these precautions we had a number of cases of malaria develop in air crews after they got back to Continental Europe. So I daresay that in any operation short of, or in an all-out nuclear war, your first concern is, or will be, sanitary engineering problems.

In the May 1961 issue of "Military Medicine" there is an article by Louis Applegate on "Preventive Medicine in the American Revolutionary Army." One of their problems was pure water. They used vinegar instead of chlorine, and were instructed to get water from the center of running streams, but they would still find the troops committing a nuisance around the camp.

I'll gaze into my crystall ball and predict with a pretty high degree of confidence that in any advanced area in any emergency short of an all-out nuclear war, your first problems would be water and feces and insects, because this always happens. I strongly recommend that you have a working knowledge of standard field methods of testing and treatment of water, and this be a part of your mental equipment. It may not be as interesting as other fields, but it will pay off sooner or later.

NUCLEAR POWER PLANT SURVEILLANCE AT A REMOTE RADAR SITE

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Hq ADC, Ent AFB, Colorado

This week the reactor core is being delivered for the PM-1 Nuclear Power Plant nearing completion at Sundance AFS, Wyoming. With on-site arrival of the nuclear material, medical service surveillance over the power plant operation enters routine phases of application.

Specifications and schematic drawings of the PM-1 nuclear power plant are contained in the handout brochure. Briefly, this plant will supply the electrical power and space heating requirements for the operational facilities of the 731st Radar Squadron being built atop Warren Peak in eastern Wyoming. Operating experience gained at a typical air force field installation will serve to guide future applications of controlled nuclear power within the military establishment.

The PM-1 facility is the first Air Force venture into the utilitarian use of nuclear energy in a field situation. As such, it has posed many new problems for staff agencies of the Air Defense Command. Operational and support requirements differing greatly from routine Air Force concerns have demanded solution. Training of the operating crew, personnel rotation, special equipment, resupply, Civil Engineering utility operations, and medical support are only a few of the areas involved. I am going to discuss only the factors involved in developing the Air Defense Command medical support rationale for this unique operational mission. At this point, I should like to review some pertinent facts. Power is obtained from a reactor through release of the binding energy when heavy uranium fuel atoms split into smaller atoms. This produces heat which can be used for mechanical power. However, during the nuclear fission process, some energy is given off in the form of ionizing radiation. About 3% of the reaction energy is released in the form of prompt gamma radiation. Subsequently to the initial uranium fissioning, the variety of lighter element fission products created continue to give off ionizing radiation as they decay to ultimately stable elements. For the PM-1 reactor, 10 grams of uranium fuel per day are converted into radioactive fission products. A few milligrams of these are enough to make this room uninhabitable.

Ionizing radiation, be it due to alpha, beta, gamma, neutron or other types, is damaging to living organisms. The degree of damage sustained is a function of the length of exposure and the energy imported to the tissue, which equals the absorbed dose. Please bear in mind that there is no such thing as a "safe" level of absorbed dose. No matter how small the dose, commensurate cell damage will result from it. The usefulness of atomic energy, however, dictates that we must accept some

adverse effects in exploiting it. The basis of all current ionizing radiation exposure levels ultimately comes down to benefits versus harm from the dose absorbed. Benefits obtained must be worth the risks taken. An often used analogy is the automobile, which kills and injures more people than any other man-made device. Admittedly, this toll could be greatly reduced if permissible speed limits were dropped to mph. However, this would nullify its usefulness.

It follows that practical ionizing radiation exposure levels are necessary. The applicable N.C.R.P. exposure limits for the PM-1 environment are as illustrated. Ideally, in the case of the occupational worker, these should neither be so low that they interfere with necessary operations nor so high that they subject the worker to perceptible bodily harm over a working lifetime. For the population-at-large, cumulative man-made ionizing radiation exposures must be kept below genetically significant levels.

The preceding facts delineate the Medical Service area of concern here. I will now mention the ways and means adopted to provide requisite medical support for the PM-1 operation.

First echelon medical support for the nuclear power plant personnel is afforded by the Military Outpatient facility for the radar site. At a typical radar site, this facility is staffed by two Independent Duty Technicians. For the Sundance AFS mission, staffing was augmented by one Preventive Medicine Technician. Routine surveillance and monitoring services will be extended from the on-site facility, with periodical consultant engineer field evaluations provided by the Division Sanitary Engineer.

Back-up medical support for the site is furnished by the 821 Medical Group at Ellsworth AFB, which is the support base for Sundance AFS. In addition to these capabilities, special radiobiological analyses are obtained through the resources of Walter Reed Army Hospital and the USAF Radiological Health Laboratory.

Numerous medical examinations of the reactor personnel will be completed by the time the reactor goes critical. These include whole body counts to determine existing body burdens of radio-isotopes, physical examinations and bioassays of body fluids. These examinations will be repeated at periodic intervals to detect changes attributable to exposure to ionizing radiation.

During operation of the reactor, ionizing radiation from the nuclear material and its waste products pose obvious threats to the PM-1 personnel. Basic protection is provided by the biological shield of compacted earth surrounding the primary units and, in a vertical direction, the shield water in the primary tanks. However, mistakes in technique during hot waste handling, equipment malfunctions, and freak accidents can and do occur around reactors which result in the

spread of contamination. Automatic warning devices give notice of changes in environmental levels. However, the worker himself must be continually monitored to reveal his actual personal exposure and ensure he does not exceed established limits.

The presence in the PM-1 crew of a health physics complement necessitated a precise delineation of radiological health responsibilities. These health physicists are responsible to the PM-1 unit commander for the safe operation of the facility. The medical service has neither direct supervisory nor operating control of these personnel. Therefore, a policy decision was cleared with the Atomic Energy Commission that the reactor crew will conduct its own day-by-day program of personnel and facility monitoring. The Medical Service will establish and maintain an independent surveillance program. This is in accordance with long established custom that the Medical Service will not engage directly in industrial operations but rather will monitor health hazards associated with an operation. It preserves the time-tested check-and-balance evaluation of the adequacy of internal control mechanisms.

Thus, the PM-1 health physicists will monitor reactor crew exposures through the application of safe working procedures and the use of individual pencil type dosimeters and a hand-and-foot counter. As a check on this, both beta-gamma and neutron sensitive film badges will be issued, collected, read and permanently recorded by the Medical Service through its established resources. The health physics personnel will routinely monitor the plant environment with the installed air monitoring and gamma radiation detection equipment, together with portable survey meters. Periodically, the Medical Service will perform independent checks of the plant internal environment using field RADIAC equipment. This surveillance will be conducted in the same general manner as for all other occupationally hazardous environments found in the industrial operations of the Air Force. Besides ionizing radiation, general industrial hygiene concerns such as the usage of the toxic solvents and chemicals, heating, ventilation and illumination will be involved. Food and drink practices also need to be closely watched. The return of soft drink bottles to general circulation from such an environment would not be permissible, for example.

Turning to considerations of the health of the population-at-large in the vicinity of the reactor, it is apparent that a wide field of endeavor is involved. Because of the absence of controls for the external environment and the rights of the people in it, ionizing radiation levels for the general public, livestock, crops, watersheds and milksheds are much more stringent than within the nuclear power facility. The adverse public relations and legal and political difficulties that can arise from minor incidents and the remote possibility of major accidents warrant strenuous efforts to avoid. Monitoring and prevention of the release and dispersal of radioactive

contamination require constant attention and expense, but decontamination of an area may involve far greater grief and cost.

The primary source of area contamination, excluding a nuclear excursion is the by-product and waste materials associated with the nuclear reaction. Radioactive gases accumulating in the primary loop water are passed through a scrubber and flame arrestor and fed as off-gas to the shield water cooler vents for dilution and atmospheric release. Radioactive constituents in the reactor water become transferred to the demineralizer bed. This hot material is flushed into a buried waste tank for concentration and storage. Spent fuel fission products build up constantly in the core. These wastes require careful safeguarding. Their escape into the atmosphere or ground waters could result in widespread contamination.

Monitoring of the external environment of the PM-1 reactor will also be accomplished as a medical support activity. In addition to environmental surveys already performed by the Martin Company, the Medical Service is accomplishing its own base-line survey to obtain an independent set of reference data. Water, soil, pasture grass and other vegetation samples have been collected over a wide area surrounding the site. These samples are analyzed by the USAF Radiological Health Laboratory as a service rendered by AFLC. At periodic intervals, the same sampling locations will be retested to provide data on radioactivity levels in the region and serve to monitor the power plant operation.

The Medical Service areas of interest in a field nuclear power plant operation have been discussed. The surveillance requirements entailed fall, for the most part, in the province of the Medical Service engineer. Expanding utilization of atomic energy within the Air Force points up the need for increased sanitary engineer familiarization with this specialty field.

RESPONSIBILITY OF THE AIR FORCE LOGISTICS COMMAND
IN THE AIR FORCE RADIOLOGICAL HEALTH PROGRAM

Captain Carl J. Weinberg, MSC
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I would like to start out by giving a minute of philosophy which then makes the rest of the speech almost superfluous. If you read our job description in AFR 160-17 you would come to the conclusion that if we were all competent in those fields mentioned in that regulation, we would obviously be the world's best educated individuals. We find that, depending upon our assignments, our day-to-day problems are channeled into certain areas that are covered in this great, big broad field. It happens that in the area to which I am assigned, the day-by-day papers that stack up on my desk are involved with problems of health physics, radiological health, or whatever you might call it.

The whole point of getting up here and talking is to tell you that because of this particular position, I have available to me facts and information regarding this area of responsibility that you may not have. In the same way Captain Kittilstad has facts and information regarding fluorine spills, because he happens to be at Edwards where they are doing this work, that a lot of don't have. If you get into a problem in a particular area, please, at least know where the person is who is working in this day by day, and give him a call. We are not such a great big organization that you can't pick up the phone and just call up and ask, "What's the story on this, that, or the other thing." The same holds true if somebody comes in asks me, "What's the problem with fluorine spills?" I'm going to get on the phone and call Owen and say, "What is it?" I can't keep up with all the work that is going on. So, very quickly, I am going to cover the three big areas that we are in, tell you what we are doing, and leave it at that. If you've got any problems, I'll put my phone number on the bulletin board -- Wright-Patterson AFB, Ext. 62331.

Under existing regulations there are three big areas in which AFIC is involved: First, the USAF Radioisotope Committee; Second, the USAF Radiological Health Laboratory; Third, AFIC responsibility in consultant services, including health physics. Now, in the USAF Radioisotope Committee, we are the central focal point for all licensing of radioisotopes in the Air Force. We are the official agency that deals with the Atomic Energy Commission in the licensing and regulation of radioisotopes. This is not only for Air Force people, but - for coordination purposes - the Atomic Energy Commission sends through

the Committee all applications from private companies where they will apply radioisotopes on Air Force Bases or Air Force installations. As you can well imagine, this results in a veritable flood of paper work.

It was realized five or six years ago that there are certain problems peculiar to the Air Force with regard to radioisotopes, especially with regard to licensing. These problems led to the USAF Radioisotope Committee holding an Air Force-wide license for certain categories of radioactive materials. I hadn't intended to do this, but because of some of the questions I've had, I would like briefly to tell you those isotopes which are licensed on the Air Force general license and whose regulations and handling are covered under the "Tech Order" system. Now it took me a year and a half in the Medical Service to find out where in the Hell I could get them. But you can get them - your Inspector General keeps a Tech Order library. So if you people are not familiar with tech orders and you haven't screened through the multitude of items that they cover, I would suggest that you do so.

The USAF general license covers the following items: It covers the luminous markers on aircraft. Check sources for the PDR-39, PDR 43-A and PDR 43-B are covered, so that the individual base is not required to get a license. Additional requirements come out of the supply channels, such as a statement on the order or requisition that the person is cognizant that the check sources involved are radioactive, but this is all that is required. The Krypton 85 batteries on the re-entry vehicles and also the Cobalt 60 calibration sources are covered under the Air Force license, and their handling, disposition, requisitioning and approval are covered under a technical order in the same series - OO-11ON-3, I believe. Also, the Plutonium 239 sources are calibration sources covered under the same system. The only other item that is covered under this, Polonium 210 static bars, which I think someone mentioned and talked about the other day.

Let me say this, that sitting where I am, being involved in holding this general Air Force license, I'm really sitting in an isolated ivory tower, as to what is really happening to these items down in the field. I would like very much to get information from you people if you run into any problems with regard to any of these items. Yesterday it was brought up that two of the polonium 210 bars were found to be leaking. We are involved in reviewing the specifications, procurement actions and write-up of the procurement orders for these items. If we require a change because of field use, we are in a very enviable position in that I can do something about it. So this is sort of a two-way street; the more I know about the problems you are running into with regard to these items, the more I can do in trying to help make it easier for you.

The other flood of paper work has to do with the special requirements for the Cobalt 60 and the PU 239 calibration sources through the PMEL Laboratories. This PMEL Lab system that's going into effect is actually a laboratory at every AF base which calibrates the ordinary instruments used in the day-to-day operation of the maintenance of aircraft. This is a sort of central calibration laboratory and the calibration of radiac instruments is just another one of their jobs. Being where I am, all I see is the paper work and it's sometimes amusing to read through these applications. There are such things as people asking for "alfa" sources! I wrote him that I suggested his local feed dealer, but are you to assume that such an individual really doesn't know what he is doing of that he just made a mistake here. It's sometimes difficult to make up your mind whether you ought to approve an individual to use the source or not. We may get a very elaborate description of the safety precautions they will take on the calibration range, using a PU 239 source! It makes you wonder! Do these people really know what they are doing? In many cases on these applications I find that the base sanitary and industrial hygiene engineer is named as the individual who is the radiological health officer, and then I begin to wonder whether you people ever know you are on these applications. But I won't take any longer on that particular problem.

We get involved in a variety of interesting uses of radioisotopes. The use of Zinc 65 tipped bullets for scoring systems on firing ranges, for instance. The same principle will be used on the Nike-Zeus scoring system at Vandenburg. Additionally, we get involved in reviewing clinical isotope licenses from the health protection aspects.

With regard to licenses, I want to mention three items that have given us a lot of trouble: (1) The Atomic Energy Commission is on a crusade with regard to leak tests. The procedures that are now in the tech orders are really not accurate. We're in the process of changing these. I would like to have each one of you go down and find out at your PMEL Lab if there is any record of a leak test. Every copy of an AEC Compliance inspection that I get mentions this particular item. The T.O. says they will be leak-tested every six months and a record of this will be kept. This is done at very, very few places. (2) The AEC requires that a record of survey be available to show that someone has been down there and surveyed the facility, if there is a by-product material in use. A lot of people have indicated to me, "Yeah, we go down and make a survey, but we never write it up." I'm just saying this because the letter on these inspections goes to the Base Commander, and he has to have an answer to these things. (3) I want to mention the use of Magnesium-Thorium alloys. Magnesium-Thorium alloys do not require a license as long as they are in a finished product. They require AEC licensing if you are going to perform any kind

of machining operation - that is, if you are going to weld on them, cut them, or anything that produces dust or fumes. New aircraft C-140's and C-141's are using natural uranium or spent uranium for control cable counterweights. This also does not require AEC licensing, as long as no particular machining operation is done on the counterweights. The Code of Federal Regulations has been amended; you don't need a license to put them on and off the aircraft, to store or to handle them, as long as you don't cut them apart.

The other area of responsibility is the Consultant Health Physics Services. Here we get involved in helping out on the PM-1, Radar X-rays, Medical X-rays and Dental X-rays. We are in sort of a pilot study now on the use of the U.S. Public Health Service Dental Sur-Pak technique for the screening of dental X-ray machines. We have mailed this out to our dentists and hope to get some results back on this. This is a very rapid means of screening dental X-ray machines. If any of you are interested in trying it within your commands, get in touch with me, because a lot can be done in this way.

A multitude of calls are received on the daily problems that arise. The big problem right now is the identification and marking of radioactive materials. There are so many military specifications, military standards, etc., that it is virtually impossible to tell really what you ought to do on this particular problem. All I can say is that this is a problem area, and I would like to ask you people, please, not to make a crisis out of it. We've already had this happen. On one base we found something like 170 items which gave a reading on a GM survey meter, but which were either not marked or not known to contain radioactivity. So the present standards are all being changed to reflect marking requirements, in a Military Standard 129-C, which is a packaging standard. If you will get one, take a look at this and I think the problem might disappear.

This is a general synopsis of AFIC's involvement in health physics problems. This is what I have to worry about day by day. If you have any problems along this line, I will be glad to answer any questions while I am here. Otherwise, I'm always available at Wright-Patterson, at Extension 62331.

INDUSTRIAL HYGIENE PROBLEMS OF THE TITAN II MISSILE SYSTEM

Capt. C.H.Powell; Capt. B.S.Smith; Lt.J.O.Pierce II
Lt. R.G.Nadeau; Mr. E.G.Robles, Jr.

Speaker: Captain Billy S. Smith, USAF, MSC
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With the rapidly changing and evolving weapons systems currently in use and under development, it has become imperative that industrial hygienists become familiar with a number of widely-varying problems relevant to these systems. (17)

In studying the industrial health hazards inherent in one of these new missile systems, the Titan II, it early becomes apparent that conventional methods would not suffice in the collection of representative environmental samples, nor in all cases would known procedures result in adequate analytical accuracy. (1)

A consideration of the materials used in the Titan II system (nitrogen tetroxide, hydrazine and 1,1-Dimethyl Hydrazine (UDMH), as well as their low-and-high-temperature decomposition and combustion products, showed that an exceedingly complex oxidation-reduction system existed, and that no adequate evaluation under all conditions could be completed without detailed and exhaustive studies.

It was felt that an experimental program to determine the proper methods of sampling and analysis could be undertaken with profit. As a preliminary step it was essential that valid methods of sampling and analysis for each of the three original components of the system be available, not only macroscopically, but for trace quantities as well. Numerous excellent analytical methods existed for quality control work (13, 24, 25) and for individual components in the percent range (7, 9, 12, 14); however, information for analytical procedures to be used in the microgram range were adequate only for NO_2 and even then valid only when the analysis was performed after a predetermined elapsed time (22).

Information as to N_2H_4 , UDMH, and their various decomposition products was in large measure lacking, or based on theoretical calculations of firing conditions (10) and was in some instances contradictory (16, 18).

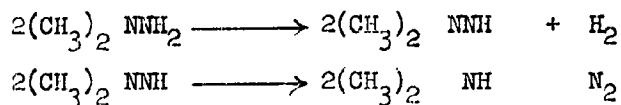
Early experimental work on NO_2 and hydrazine proved that existing methods for their determination would in all probability suffice with only minor modification. Previously published work was verified, and no insurmountable interferences from UDMH were discovered (2, 3, 5, 6, 22).

The most promising methods were the use of p-Dimethylamino Benzaldehyde for Hydrazine, and Diazo coupling of N-(Naphthyl Ethylene Diamine Hydrochloride) with sulfanilic acid for NO₂, the sole difficulty with the latter being the necessity for immediate analysis, due to oxidation with moderate rapidity under normal conditions (23). Analysis for NO₂ should be carried out in the field, using the Saltzman reagent adapted for field use (22). If field analysis is not possible, samples may be collected in evacuated 500-milliliter gas sampling tubes at ambient temperature and transported to a laboratory for analysis. Figure 1 shows the rate of oxidation of NO₂ collected as described above, and under normal sampling conditions² (20°C and 760 mm Hg.)

UDMH was expected to cause difficulty, as it reacts with a wide variety of materials and forms an undetermined number of products on decomposition under ambient conditions. It appeared necessary, from the recommended MAC values (30, 31) and other considerations, to develop methods of analysis sensitive to UDMH in the 0.1 - 1.0 microgram range. It was found that electrometric and redox methods for determination of UDMH were either insufficiently sensitive for the desired range, or non-specific.

Attempts to analyze for UDMH in air by IR spectrophotometry (18) were promising in relatively high concentration (ca. 100 ppm). As the vapor density of the gas was lowered, it became evident that this method would not be adequate for a two-fold reason. First, the "specific" absorption maximum for UDMH at 11.0 microns became reduced at a much greater rate than accounted for by calculation, and new absorption peaks began appearing at 9.8, 11.3 and 4.35 microns. Subsequent samples of UDMH from Aerojet and Eastman showed similar behavior. Insensitive recalibration of the instrument (Perkin-Elmer Model 21) showed that the peaks were real, and suggested decomposition of the material into as yet unknown reaction products. Careful study of the trace elements suggested that at least one of these products was Dimethylamine.(4)

Rollefson (21) discusses the mechanism of photolysis of Hydrazine to Ammonia, Hydrogen and Nitrogen. A similar decomposition could account for the production of dimethylamine.



Investigation of different diluting gases showed that dilution of freshly distilled UDMH with helium gave results as reported in the literature (18). Dilution with laboratory air and humidified oxygen (relative humidity 20% in both cases) showed the above-described

changes. Since the behavior of UDMH in normal atmospheres was of primary interest, no experimentation with dry oxygen was performed. It was also noted that in aqueous solutions (pH 2) the decomposition was markedly retarded or did not seem to occur in concentrations of less than 1000 ppm.

UDMH in which a marked degree of decomposition had occurred, as noted by a high Saybolt color index, distilled at atmospheric pressure under dry nitrogen, resulted in:

(1) A clear mobile liquid, boiling from 62 - 64° C. (BP of UDMH at 760 mm Hg to 630 mm Hg.)

(2) A yellowish-white crystalline solid formation in the condenser.

(3) A heavy, black, viscous, oily residue.

(4) An uncollected gas, with a pronounced "fishy" odor.

As mentioned above, portion No.1 gave no reaction with Chromotropic Acid. Portions No.2 and No.3 gave strong reactions with Chromotropic Acid. The crystalline solid was tentatively identified as 1,1 Dimethylhydrazonium 2,2 Dimethyl Carbazate, as previously described. It was therefore decided that without a more comprehensive study, infrared methods would not be utilized to determine UDMH in air.

It was reported that Chromotropic Acid in concentrated Sulfuric Acid determined UDMH rapidly and accurately. (3) Studies in this laboratory showed this to be true of UDMH with which no special precautions had been taken in storage and use. Freshly redistilled UDMH, however, did not give the reaction at all and it appeared certain that again it was one of the decomposition products which was being determined.

Feigl describes the reaction as being specific for formaldehyde. (6) Related investigation of aqueous solutions of UDMH with Schiff's reagent showed definite presence of aldehydes; following the reaction by means of Chromotropic Acid over a 30-day period showed that formaldehyde built up to a maximum at approximately 22 days in dilute solutions, after which the concentration tended to be reduced. The concentration of UDMH was reduced at a much greater rate and some intermediates as yet unknown were postulated. Fig. 6.

It was found that the MSA field sampler operated as specified by the manufacturer; however, moderate quantities of NO₂ seriously interfered with the reaction. It should be pointed out that, due to the probability of interaction, it is possible for UDMH and NO₂ to be present in the air together at comparatively high concentrations - up to 1000 ppm and probably higher. (19).

UDMH decomposes in aqueous alkaline solutions, whether exposed to the atmosphere or kept stoppered in reagent flasks. Since UDMH is a basic compound, a solution of the compound will be alkaline if no acid is added. In weak acid solutions (pH 2) the compound up to 1000 ppm is stable for at least three months and probably much longer. In slightly alkaline solutions (pH 10) concentrations ranging up to 50 ppm were analyzed daily for UDMH in an attempt to derive a reaction rate for UDMH decay and the corresponding rate for the formaldehyde formation. There are evidently sufficient competing reactions in the system to prevent derivation of a reliable rate for either compound. It was noted, however, that the UDMH concentration dropped rather rapidly for the first eight days, leveling off to essentially no detectable UDMH in even the 50 ppm solution after 18 to 20 days. Also, a gradual rather than a rapid formation of formaldehyde was experimentally suggested, which indicated the possibility of an intermediate complex (Fig 6) - possibly a hydrated form of UDMH, either or both tetramethyl tetrazine and N-Methyl Methylenimine.

In a further attempt to determine decomposition and/or degradation products, the reaction of UDMH with trisodium pentacyano amino ferrate, a procedure was developed which seems to be satisfactory under rigorously controlled conditions, such as pH adjustment, measuring absorbance at exact times and the absence of interfering ions (Fig 2, 3, 4). It is exceedingly difficult under field sampling conditions to meet these analytical requirements. Since UDMH is rather unstable in alkaline solutions and degraded to possibly several products, a limited study was undertaken of degradation products in air, soil, and water. It was determined that UDMH vapor did not decompose, rapidly at least, in dry air or nitrogen, while it did decompose quite rapidly in moist air. Infrared and gas chromatographic information indicates that the products of degradation are dimethylamine, ammonia, formaldehyde, nitrogen, and possibly others, such as trioxane and tetramethyl-tetrazine.

At the present the intermediate compound or compounds have not been identified with certainty and this information may very well be the key to reaction paths and possibly some toxicological information. Also, after approximately two weeks, traces of cyanide were found in the experimental H₂O solutions. The reasons for the positive test for CN is not fully understood yet, but it did point out another very interesting problem which may confront industrial hygiene engineers in surveillance of Titan II missile sites.

SOIL PERCOLATION AND WATER POLLUTION STUDIES

It has not as yet been proven whether UDMH accidentally spilling or percolating into a stream will present a water pollution problem from cyanide or other toxic material in the water system, but indications from limited data point toward an area of considerable concern. In assessing possible water contamination, at least the following analyses should be considered: nitrite, nitrate, hydrazine, UDMH, formaldehyde and cyanide. This is not in all probability the final answer on the analytical procedures to be followed where contamination of a water supply by the fuels and oxidizers of the Titan II system or their combustion or degradation products, and investigation in this area will continue.

In pursuing decomposition studies, the effect of UDMH in solution as it percolated through the soil was investigated. The laboratory apparatus utilized for the soil percolation studies were standard chromatography columns $2\frac{1}{2}$ cm in diameter and 41 cm long, with a medium porosity fritted disc.

It was hoped that a chromatographic absorption of UDMH might occur, leading to complete decomposition or at least retention of the material. The results were not as expected. Percolation of a UDMH solution through the soil columns indicated that the reaction path may be different with soil than it was with aqueous solutions. No explanation of the differences in reaction is postulated at this time, but there is evidence of formation of from 0.05 to 0.5% cyanide, based on the amount of UDMH added to the samples. To determine whether this formation of cyanide was a peculiarity of the soil used, the laboratory conditions, or could be considered typical of the reaction of UDMH with soil, soil samples were taken off base to simulate as nearly as possible actual conditions near a rocket engine test stand. Soil was placed in a container and a UDMH solution was allowed to stand over it. Cyanide was found in both the soil and the water above the soil. In an attempt to find out what portion or type of soil was responsible for cyanide formation, the soil samples were sieved and half the sample was calcined at 1000°C for one hour to remove organic matter. The samples were charged with freshly prepared UDMH solutions, made to a saturated soil paste with sufficient distilled water and allowed to stand for 24 hours. The samples were then filtered and the filtration analyzed for CN and formaldehyde. Higher concentrations of CN and HCHO were found in the 200-325 mesh sieve cut than in any other portion. This may have been due to proportionately greater surface area.

The effect of heating the soil to 1000°C was quite noticeable. Neither CN nor formaldehyde was produced in anything like the quantity that was produced in normal soil. Apparently, either the occluded water or the organic matter present and/or biological oxidation from

microorganisms in the soil catalyzes the reaction. It is probably the organic material or a combination of the organic material and microorganisms which cause this effect, since water alone produced only traces of CN. This is characteristic of one type of soil, and the reaction path may or may not differ with other types. A more detailed study which would take into consideration soil samples of various types located in a certain geographical area would aid in this evaluation. Formation of CN and HCHO in both samples occurred in the first few inches of the soil. It would appear reasonable that more concentrated solutions would cause the formation at deeper levels as well.

A slurry of soil and UDMH was inoculated with some of the bacteria utilized in water purification plants, to determine what would happen to the purification beds if a spill occurred and contaminated the area. Surprisingly enough, the bacteria seemed to tolerate the UDMH very well, even in 1000 ppm (0.1%) concentration. Evidence indicates that at least certain strains of bacteria will not be destroyed unless concentration rises to extremely high levels. A more detailed study is required in this area of research.

COLLECTION OF FIELD SAMPLES

The sampling area, while extremely important, varies with conditions from very difficult to nearly routine and will be discussed briefly. In evaluating the possible hazards of Titan II missile sites, three primary sources of samples are readily available; e.g., water, soil and air.

In the collection of water and soil samples, the only method of preservation to be considered should be rapid transmittal to the laboratory. Although acidification of the samples will "fix" UDMH, hydrazine, ammonia, and amines, it would destroy cyanide and provide proper conditions for destruction of NO₂. Water samples should be one gallon in volume, collected in clean glass or polyethylene containers and sealed.

Soil samples should consist of five random samples taken to a depth of approximately six inches over an area of one square yard. The composite sample should be from 500 to 1000 grams in weight. Where holding ponds with earthen bottoms are used, periodic samples of the silt from the pond bottom may be submitted.

To this date, industrial hygiene investigations in this laboratory relative to atmospheric contamination from the Titan II missile system have been primarily concerned with two different types of field conditions. One is high temperature decomposition studies of

static test stand firings of the Titan II and the second is investigation of fuel spills or leaks of UDMH. Unless further experimentation proves otherwise, theoretically high temperature decomposition of aerazine- N_2O_4 is not of primary toxicological concern in comparison with low temperature combustion or accidental fires, due to the incomplete reaction which may occur. The latter should require more attention and control, as will spills and leaks of either component singly or in combination. Studies of spills of hydrazine or N_2O_4 have not been completed at this time to our satisfaction.

Obtaining meaningful data from atmospheric samples relative to combustion studies is extremely difficult. A large amount of water vapor is formed from water used as a cooling medium during static firings and from the thermal decomposition of the propellant. The micrometeorological conditions during static firings, overpressures from the firing, and the extremely short firing time (maximum 120 seconds) have necessitated the use of high volume samplers (Fig 10, 11) and/or evacuated sampling containers. (Fig 7, 8, 9).

At the present, the use of remote controlled high volume compressors (2 - 4 cubic feet per minute) and evacuated sampling containers are recommended. The laboratory is using high pressure 10-liter sampling flasks.

The samples have been collected both downwind from the static firing stands and from sampling directly at the flame bucket, with the equipment placed under the breast plate. The latter method of sampling is being employed at the present time to collect the highest possible concentration of contaminants for further development of analytical procedures.

In the studies of fuel spills of UDMH, the problems are complicated by air oxidation and the possibility of surface adsorption of the fuel on the sampling container. As has been discussed, little is known as to the path of the oxidation of UDMH, or the rate of these reactions even under laboratory condition. However, with the limited experimental data obtained, it seems the rate of UDMH air oxidation is comparatively rapid under normal conditions of temperature and humidity, and the oxidation rate may differ considerably from sampling station to sampling station, depending upon temperature, wind and humidity. Therefore, sampling devices that record total oxidation or reduction are not of great value in this type of evaluation, as they will give no indication of the rate, path, composition or relative toxicity of UDMH and its oxidation products. These instruments are valuable for use as warning devices, however, if placed in the proper locations.

In the present state of the art, collection of samples by use of high volume compressors and evacuated containers is a method of choice, and collection in 0.1 N sulfuric acid by impinger is a suitable alternate.

It is believed that this laboratory has developed analytical methods that lend themselves to atmospheric soil and water analyses for the Titan II propellants and submission of samples is invited. However, it is suggested that you discuss your particular problem with the laboratory before collecting the samples, in order that special instructions and precautions can be taken.

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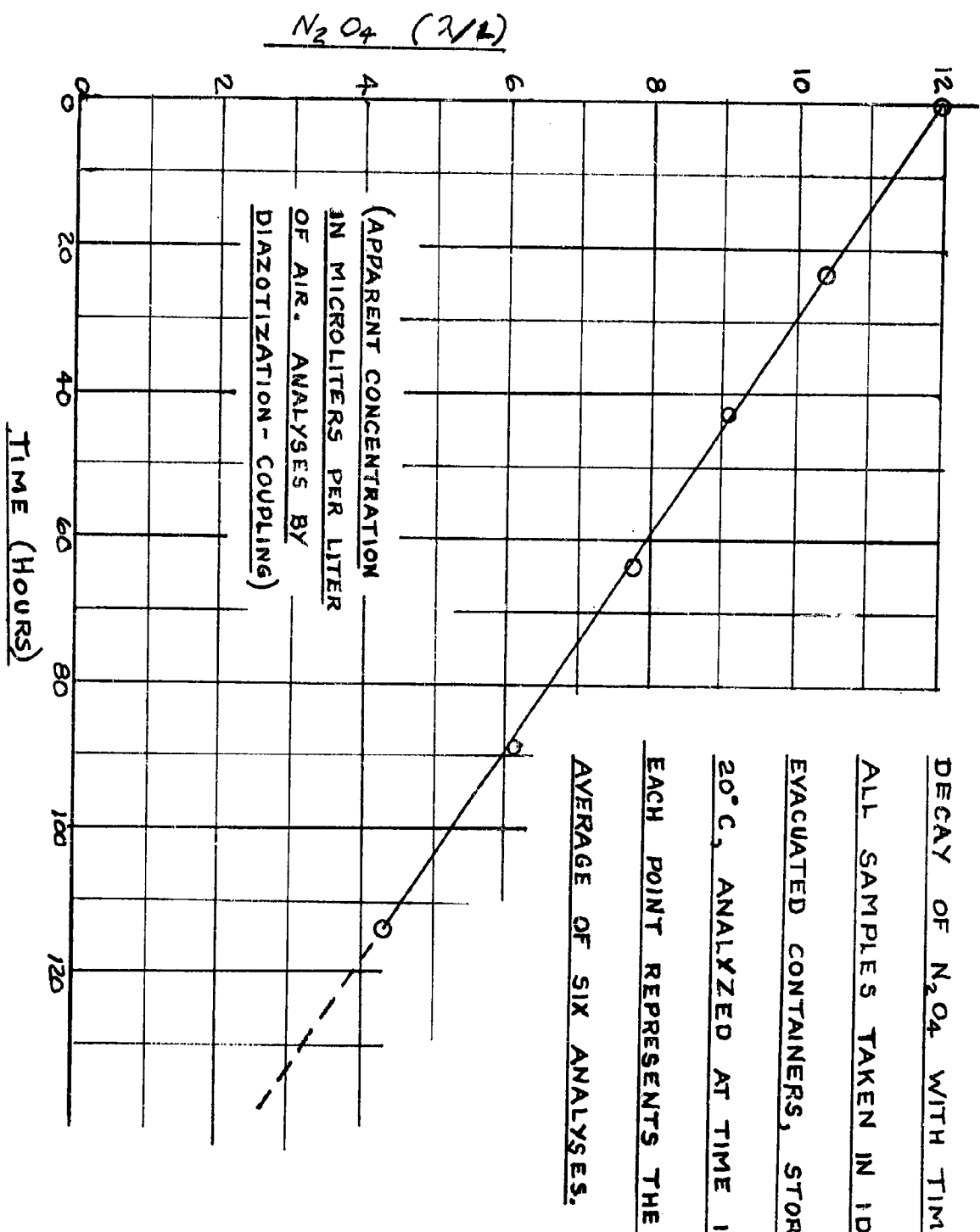
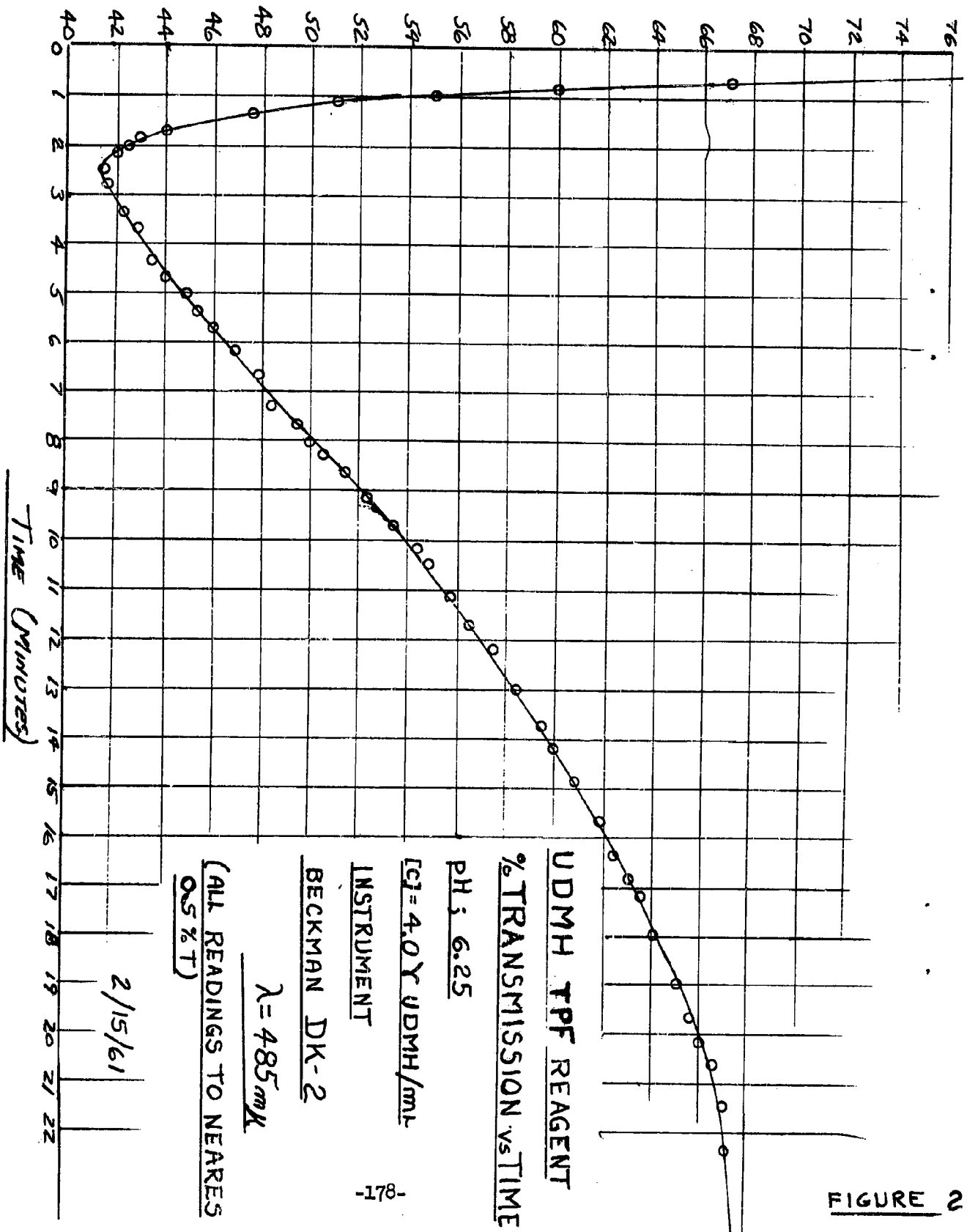


FIGURE 1

FIGURE 2



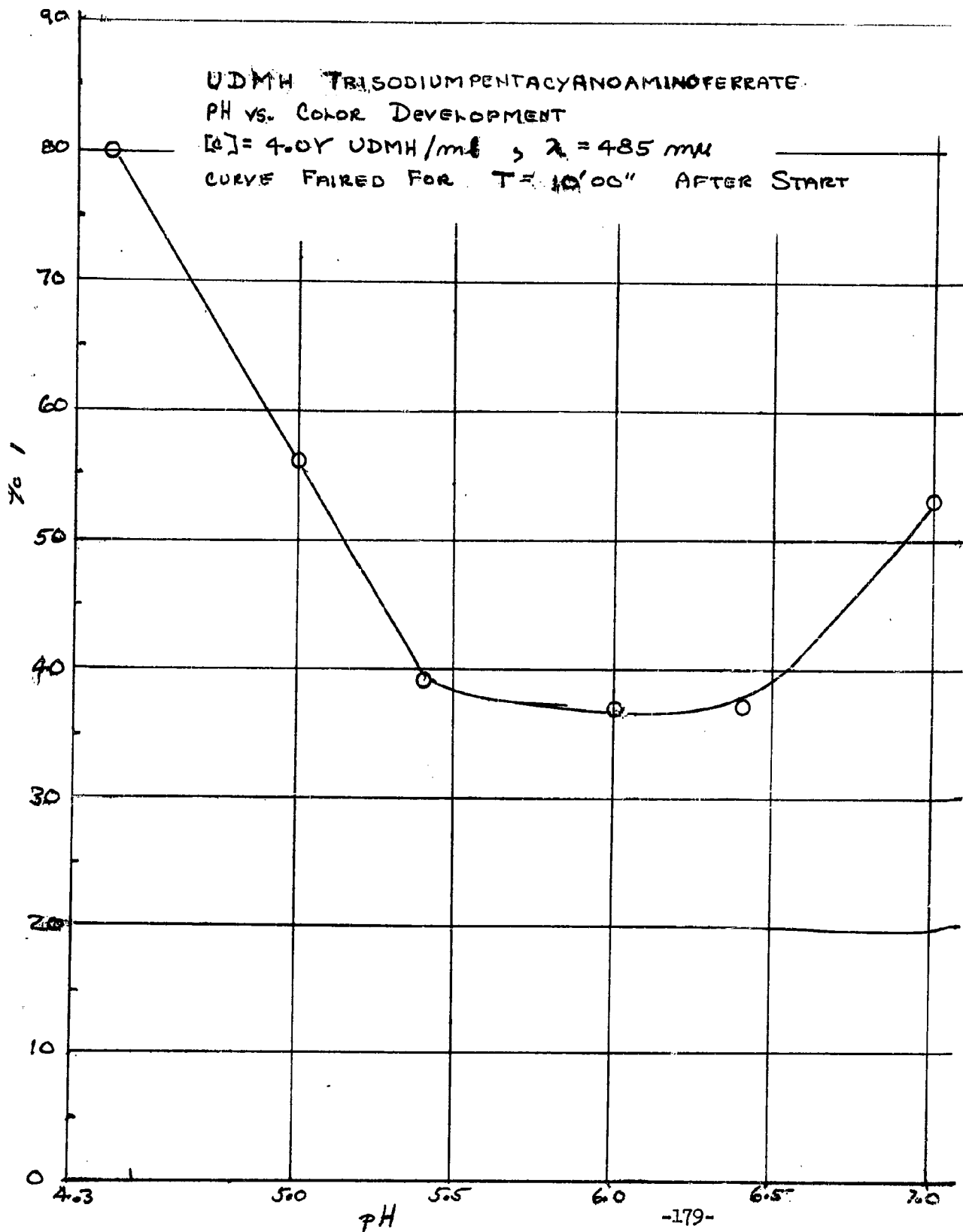
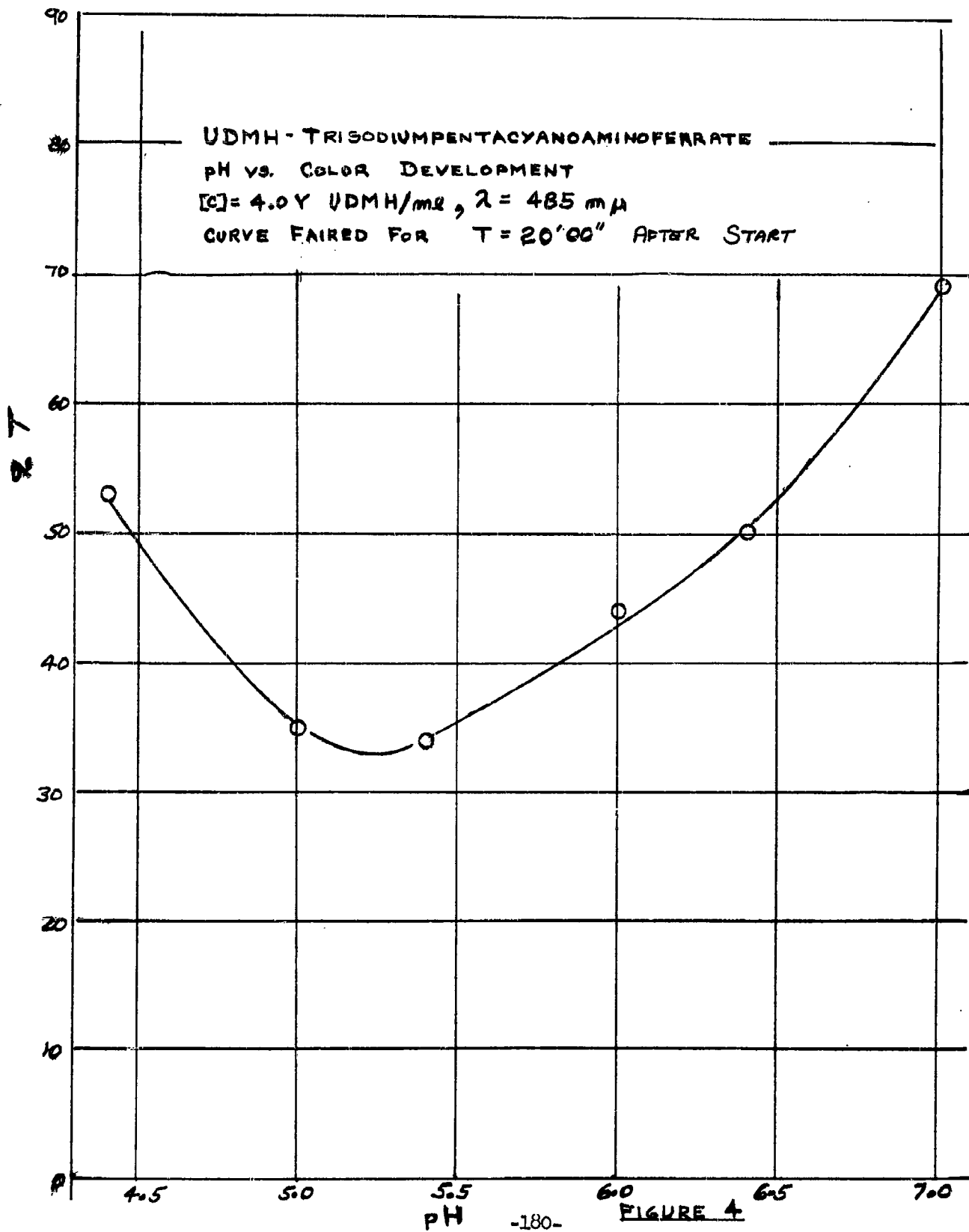


FIGURE 3



UDMH-TRISODIUM PENTACYANOAMINO FERRATE

PH vs COLOR DEVELOPMENT

$[C] = 4.0 \text{ } \mu\text{g UDMH/ml}$, $\lambda = 485 \text{ m}\mu$

CURVE FAIRED FOR $T = 30'00''$ AFTER START

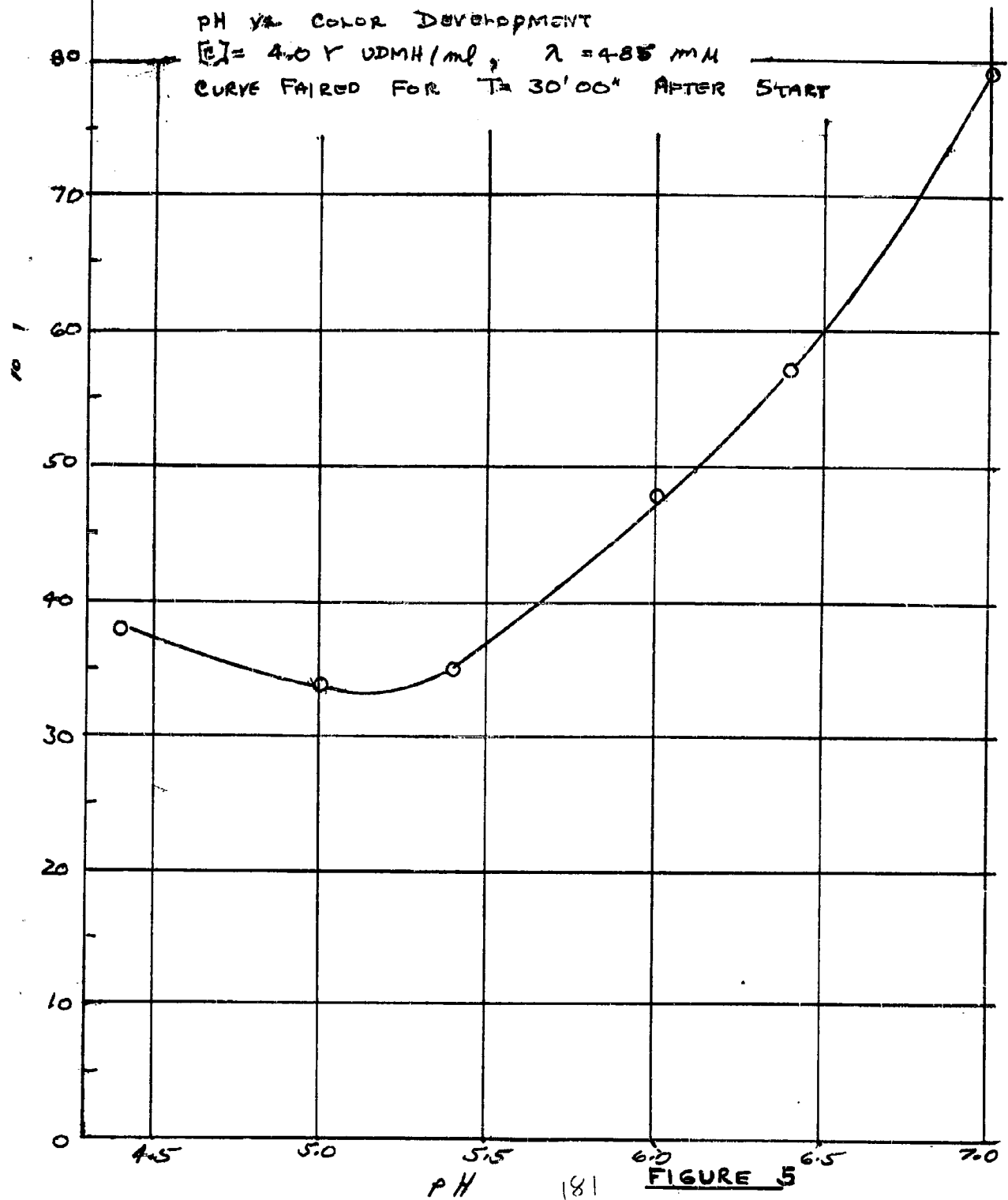
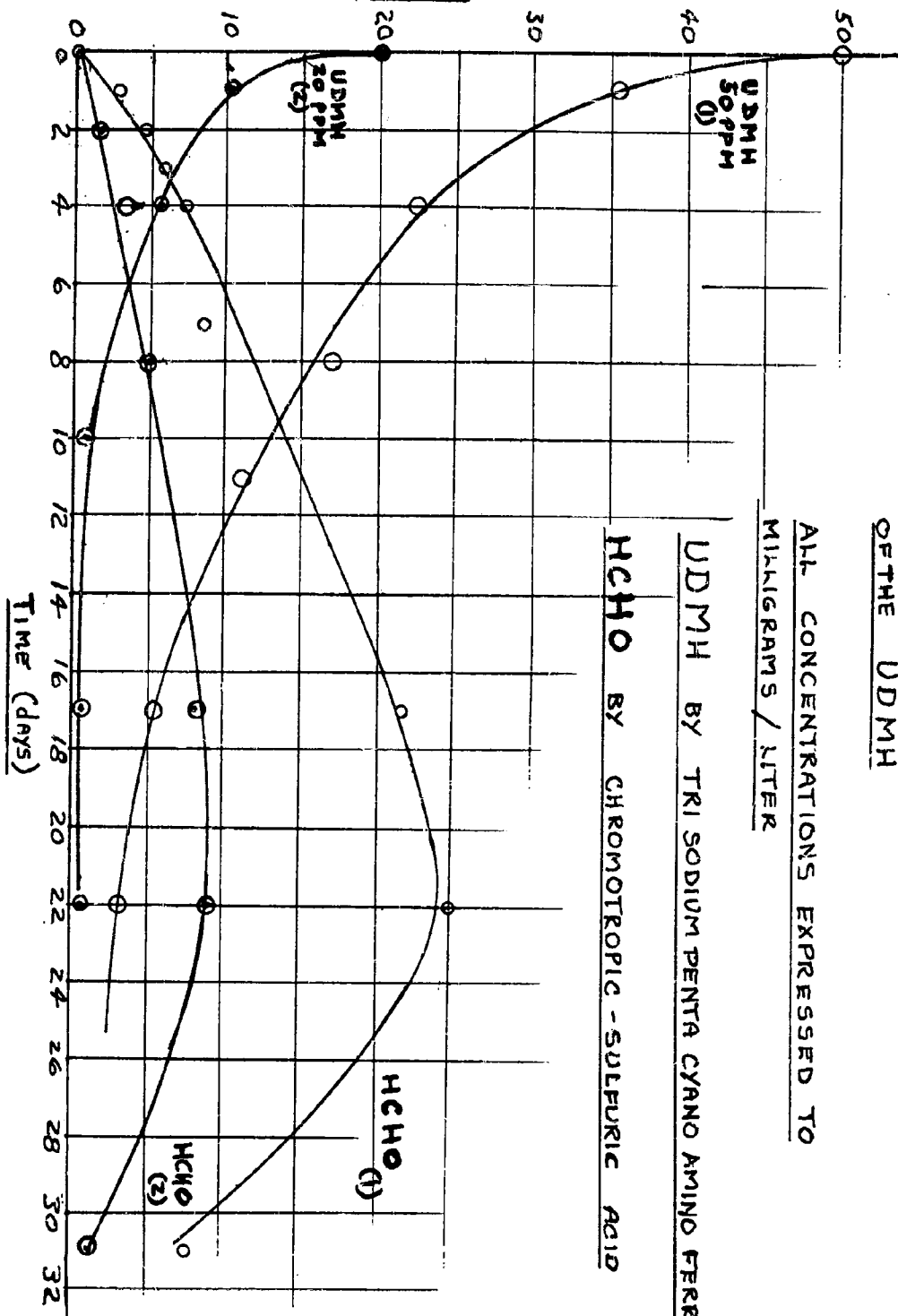


FIGURE 5

DEGRADATION OF UDMH SOLUTION
WITH TIME, SHOWING INCREASING
FORMALDEHYDE DURING THE LIFE
OF THE UDMH

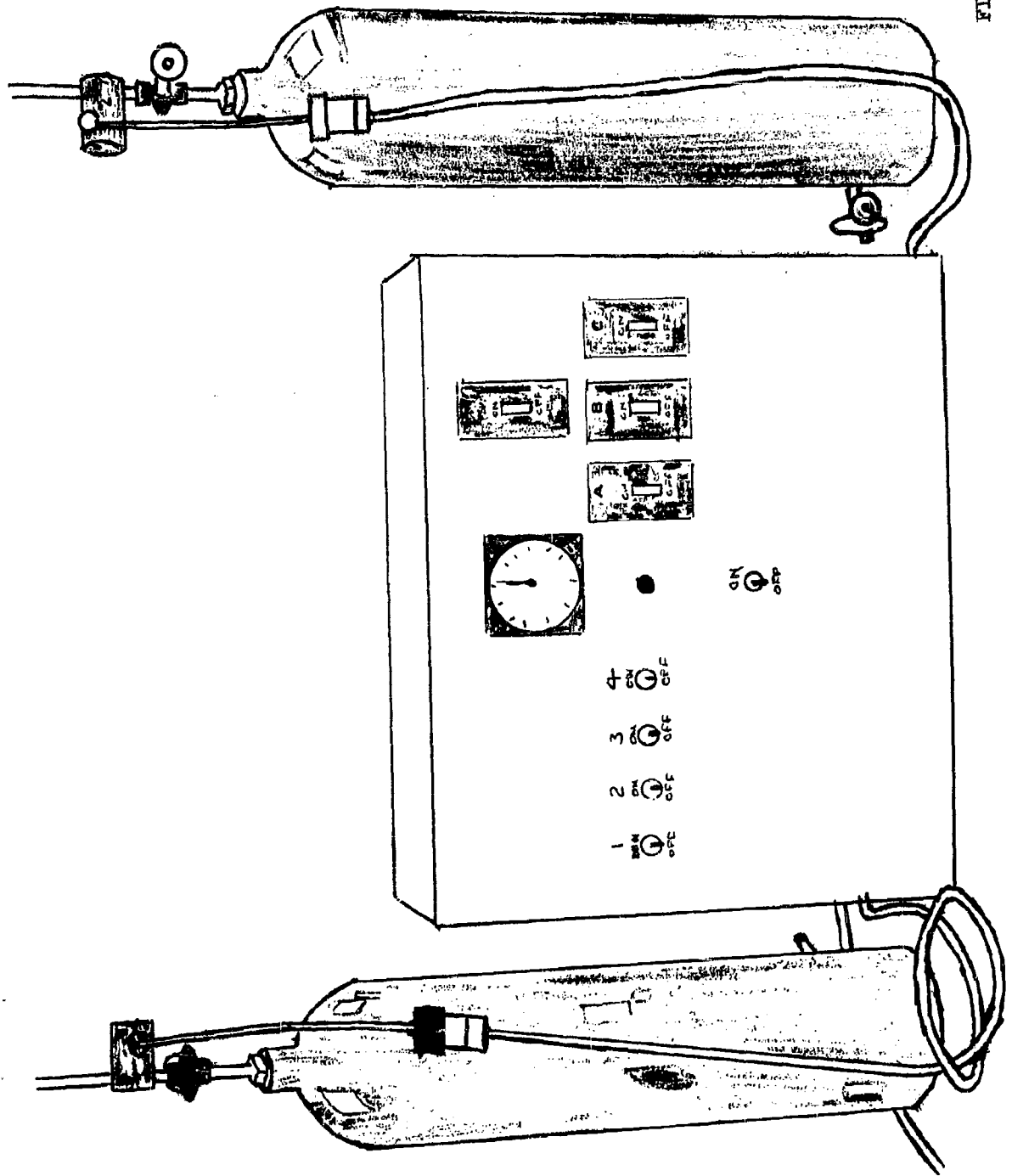
ALL CONCENTRATIONS EXPRESSED TO
MILLIGRAMS / LITER

UDMH BY TRI SODIUM PENTA CYANO AMINO FERRATE
HCHO BY CHROMOTROPIC - SULFURIC ACID



-182-
FIGURE 6

FIG. 7



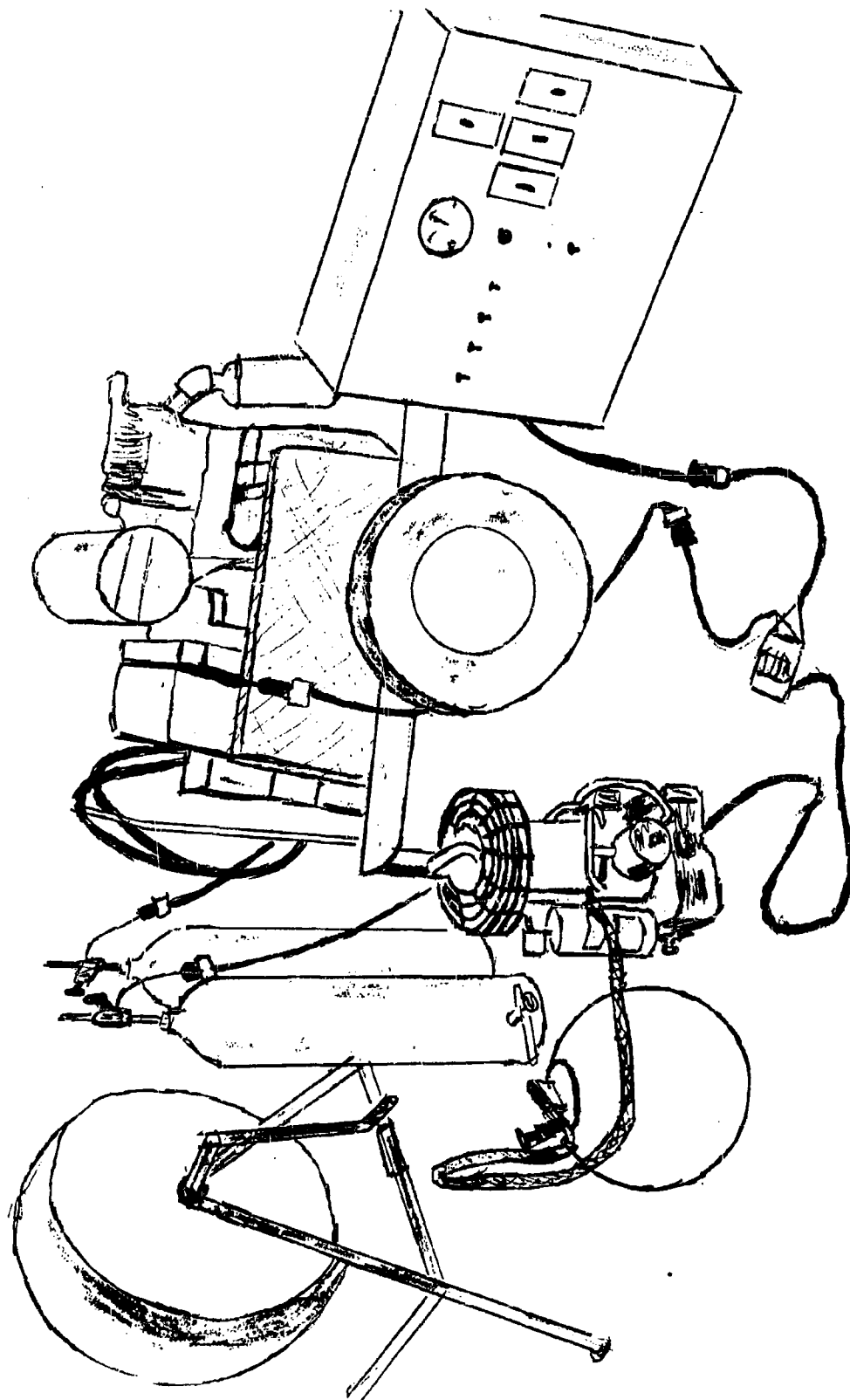


FIGURE 8

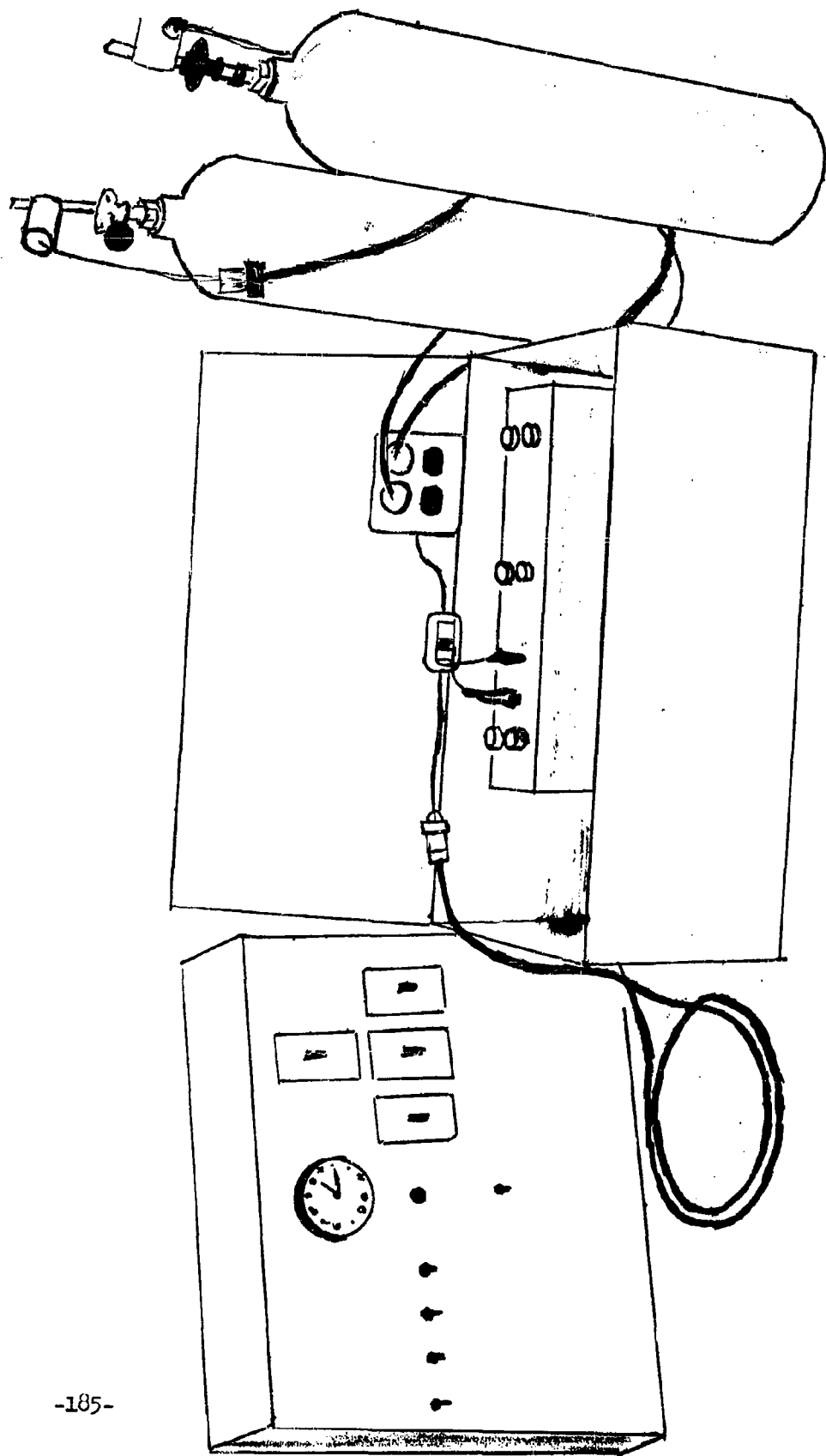


FIGURE 9

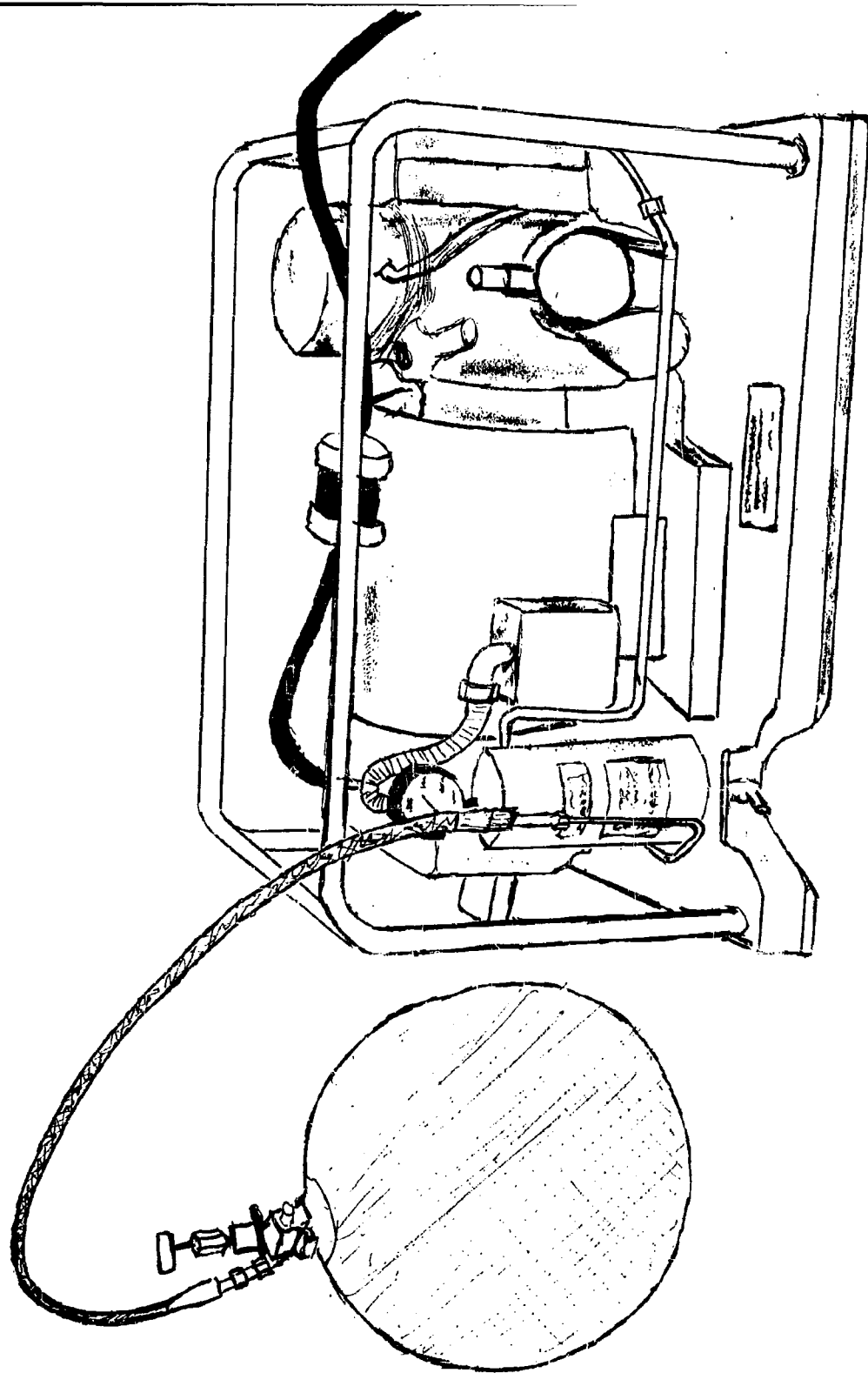


FIGURE 10

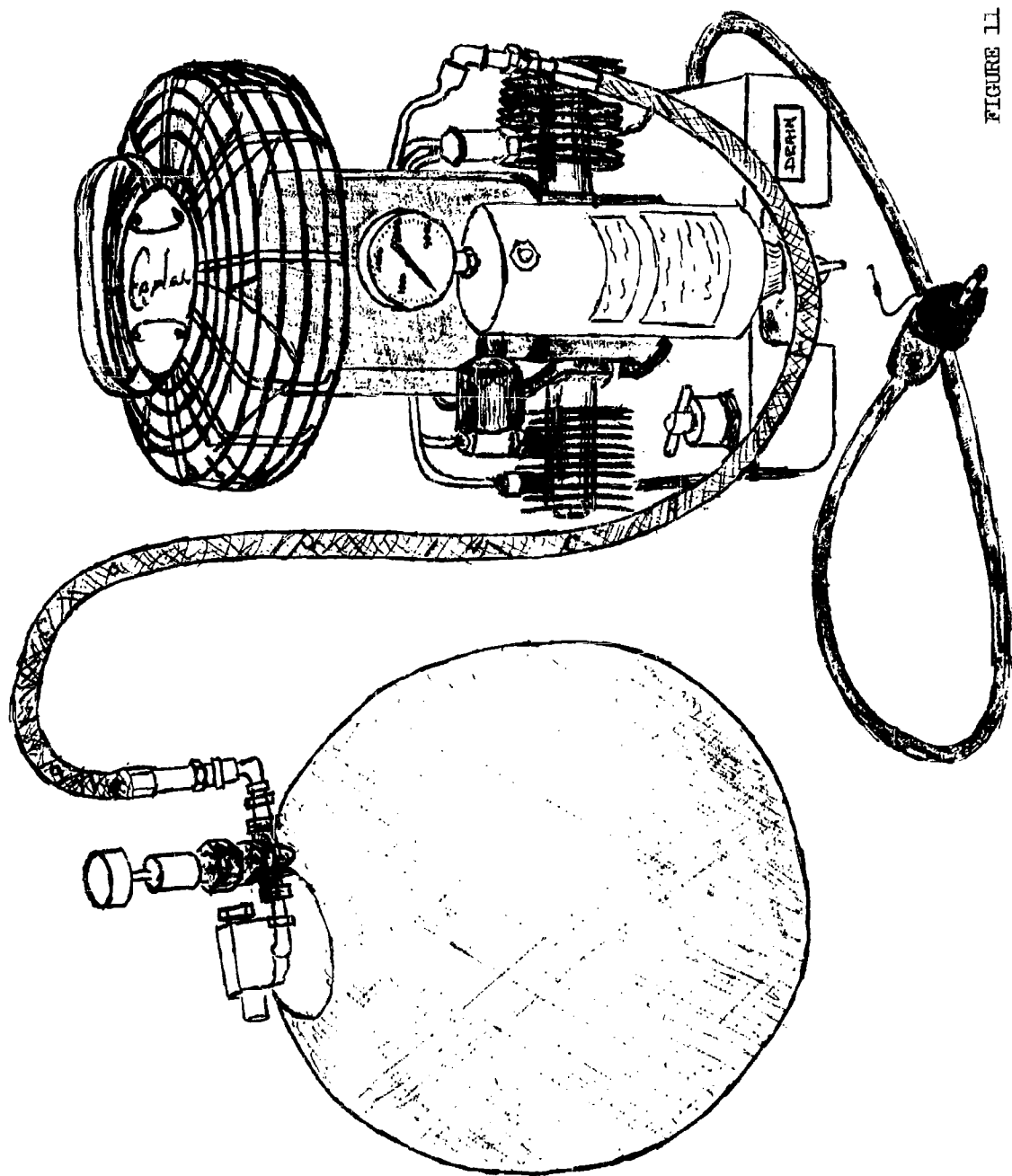


FIGURE 11

INDUSTRIAL HYGIENE PROBLEMS RELATED TO MISSILE RESEARCH

Captain Owen H. Kittilstad, MSC
Edwards AFB, California

INTRODUCTION

I've been asked to discuss Industrial Hygiene Problems related to Missile Research. Of course there are many aspects to research with which I am not familiar. At Edwards we are primarily engaged in Applied Research, so I will restrict my remarks to this area. Even with this restriction, and assuming I knew what all of these problems were, I'm sure they couldn't be covered adequately in 30 minutes. So if you will excuse the obvious loopholes in my presentation of the problems, I will attempt to summarize my interpretation of the problems as I've met them at Edwards.

I might start by basically defining "What is an Industrial Hygiene Problem?" Webster defines a problem as "any matter involving doubt, uncertainty or difficulty" or a "question proposed for solution or discussion." Industrial Hygiene on the other hand has been defined in many eloquent ways but basically it is the science or art of recognizing, evaluating and controlling environmental assaults which may impair the health and well being of workers or the community.

Quite simply then, any Industrial Hygiene Problem is any question which might arise out of an Industrial Environment which can possibly impair or improve the health and well being of people. Some might object to this interpretation of the Industrial Hygiene Engineer's role as encroaching on the responsibilities of Safety Engineers, Fire Marshals, or even supervisors and personnel relations group. I don't deny the existence of arbitrary lines of responsibility which have arisen between these groups including Industrial Hygiene. It has no place in industry in general, and certainly not in the Missile Propulsion Industry. When one's bread and butter lies in developing vehicles propelled by highly flammable, explosive, corrosive and extremely toxic material, and when each of these factors may individually or simultaneously produce a stress on a human, there is not time to debate a separate and possibly diverse interpretation of the problem. I don't wish to explore or pursue this argument today, however. The point I make is that there are not clear-cut lines between safety and industrial hygiene; between trauma and illness, between prevention of accidents or fires and controlling noise or intoxications. The reason I make this point now is that I still find fussy and bigoted thinking among Industrial Hygiene Engineers who have questioned the propriety of my interests and support in a number of areas which I will discuss today.

The 6593D Test Group is engaged in specialized research in development of rocket propulsion systems. Rocket Propulsion Research and Development encompasses new chemical compounds to provide greater power and efficiency to rocket power plants, lightweight durable rocket thrust chambers, the necessary propellant tanks, pumps, and other components making up a complete propulsion system.

The problems encountered at a static test facility are unique in a number of respects when compared to a launching site. On the one hand we are afforded certain luxuries not available to the tactical configuration such as:

1. Greater structural integrity in our run tanks.
2. No airborne abort problems.

On the other hand, our problems are made more difficult. For example:

1. The gambit of system are more numerous and diversified.
2. The frequency of firings is greater.
3. Propellant utilization is much higher.
4. All of our testing is conducted at ground level.
5. By its very nature, research necessitates that we operate on a much leaner base line of background knowledge pertaining to hazards criteria and the like.

Perhaps the principal difference between the tactical and R & D Industrial Hygiene Support Activities is the relatively greater emphasis in the latter area on projects specifically oriented to the development of data applicable to health and safety decisions. The reason for this is that to be feasible as rocket propellants, methods must be developed for handling them safely. In the search for high impulse propellants and large thrust boosters, very little, if any, compromise has been made with the toxicologists. Rather, a review of the candidate propellants would suggest to the otherwise uninformed that those responsible for propellant development were at odds-end with the medical and toxicology fraternity. This, of course, is not true. However unfortunate as it may be, medically inert materials, in general, are just not good candidate propellants for rocket engines. Thus, one of the major obstacles to developing and applying higher energy rocket propellant systems is the personnel hazard. Safety criteria studies have thus become of increasing importance to the total development program. The realization of the importance of this fact has been slow in

accomplishment. There are many reasons for this, but perhaps the most important is that those who have had the most concern, viz., health and safety personnel, do not command budgets of the magnitude to develop the criteria. Slowly, the people responsible for implementing projects and developing facilities have come to this realization through a series of painful and prolonged experiences in obtaining project approvals due to health and safety considerations. The worm has now turned, so to speak, and a rush to obtain data relative to safe siting, design and operation of rocket test facilities is being pushed by facilities types, systems managers, etc.

The industrial hygiene support activities at the Directorate of Rocket Propulsion thus fall into two categories:

1. Analysis of in-house problems; that is, hazardous areas generated by our own propulsion research efforts.
2. The more broad responsibility of developing safety criteria for universal usage.

IN-HOUSE PROBLEM

Time does not permit me to discuss in detail our in-house problems. In general, the objectives of the hazards analysis program are representative of our problems. This will be discussed later.

One of the biggest problems facing us now is how to protect the 75 million dollars we have invested in test stands that were originally located and designed to handle liquid oxygen and RP-1 fuels. The toxic problems associated with siting and design have now replaced blast and acoustics as the limiting criteria. The exclusion radii dictated by the downwind vapor hazard is of a much greater order of magnitude than that from blast and noise. What is more, it is not as predictable or as well defined.

Our approach to this problem has taken on a number of facets which are currently under study and/or implementation. Briefly, these are:

1. A comprehensive micrometeorological control network.
2. Increased communication and warning system, including a central control station, visual and audible warning systems and tighter test scheduling procedures.
3. Containment of exhausts by scrubbers, filters, etc.

4. A study of methods to mechanically assist the dispersion of exhausts by increasing the effective stack height.
5. Containment of liquid propellant spills by facilities design procedures such as diking, emergency dump tanks, etc.
6. Better defining the hazards criteria by means of experimental programs simulating hazardous incidents.

At the present time we have four positions firing pentaborane. The largest test is a 40K thrust stand. Another stand of about 5000 lbs. thrust is utilizing thixotropic mixtures of nitrogen tetroxide, pentaborane, and hydrazine. A monopropellant stand using toxic propellants is in operation. All of these propellants are also being fired in the smaller test cells using 10 to 500 lb. thrust engines. A number of cold flow studies are also in progress.

We have not experienced any serious intoxication problems to date. Several acute exposures to pentaborane and UDMH-hydrazine/Nitrogen Tetroxide have occurred. None of these could be considered as serious. Five employees have been hospitalized in the past 18 months for observation as a result of propellant exposures. Recovery was rapid and uneventful in each case with none remaining in the hospital more than two days.

AUGMENTATION HAZARDS ANALYSIS PROGRAM

The hazards analysis program is a broad term referring to tests and analyses specifically undertaken to develop operational hazards data and from this, design criteria with which to base plans and decisions regarding siting and safety consideration for space vehicles, test facilities, equipment, instrumentation and personnel.

The Directorate of Rocket Propulsion and the Aeronautical Systems Division are participating organizations working on Safety Criteria,* Design Criteria, Industrial Hygiene, Fire Protection, Protective Clothing and Disposal and Equipment and Decontamination. *(fig. 1)

The specific programs being conducted at Edwards Air Force Base, or under the cognizance of the Directorate of Rocket Propulsion are shown in Fig. 2

HAZARDS CLASSIFICATION TESTS

The Hazards Classification Test consisted of a number of experimental spills of propellants and propellant combinations. The tests were completed last month and the final report will be out shortly. The

propellants investigated were Nitrogen Tetroxide, Chlorine Trifluoride, Hydrazine, UDMH-Hydrazine Mix and Pentaborane.

The first of these tests consisted of a series of small-scale, one to five pound, spills and involved leakage of propellants singly and in pairs, spillage, tank rupture, tank vent failure, etc., and their effect on and with various construction materials. Approximately 100 small spills were conducted. The results of the small scale tests are briefly summarized in figures 3-10.

Fig. 1

Propellant Safety Programs

- . Safety Criteria
- . Design Criteria
- . Fire Protection
- . Decontamination and Disposal
- . Industrial Hygiene

Fig. 2

Safety Criteria Studies

Directorate of Rocket Propulsion, EAFB

- . Hazard Classification Tests
- . Titan II Studies
- . Road Hazards - Joshua
- . Emission Rate Study
- . Liquid Hydrogen Tests

Fig. 3

Nitrogen Tetroxide-Hydrazine Spills

1. Immediate reaction upon propellant contact.
2. Low amplitude shock waves during Ignition.
3. Extended series of overpressures shocks following ignition, apparently caused by Hydrazine-Air Vapor-Phase detonations.
4. Highest recorded overpressure of 0.75 per cent TNT equivalent.

Fig. 4

Chlorine Trifluoride - Pentaborane Spills

1. Immediate reaction upon propellant contact (intense fireball.)
2. Low amplitude shock waves during ignition.
3. Slight overpressures resulting from the reaction of Chlorine Trifluoride with the containing surfaces or pentaborane-air ignition
(weak overpressure of less than 0.0003 percent TNT equivalent.)

Fig. 5

Chlorine Trifluoride-Hydrazine Spills

1. Immediate reaction upon propellant contact.
2. Low amplitude shock waves during ignition.
3. Slight overpressures resulting from the reaction of Chlorine Tri-fluoride with the containing surfaces AND hydrazine-air vapor-phase detonations.
(largest TNT equivalent found was 0.0045 percent)

Fig. 6

Pentaborane-Hydrazine Spills

1. Appreciable delay in initial reaction.
2. Explosive reaction when spilled on asphalt surface.
3. Slight overpressures resulting from propellant reaction within combustion zone.
(highest recorded overpressure was 3.15 percent equivalent)

Fig. 7

Results of Propellants Spill Tests

<u>Propellants</u>	<u>Surface</u>	<u>Temperature</u>	<u>R.H.</u>	<u>Results</u>
Hydrazine	Dry Asphalt	98	18	Small Decomposition
Hydrazine	Dry Concrete	98	18	Small Decomposition

Fig. 7 (continued)

Hydrazine	Dirt	98	18	Small Decomposition
Hydrazine	Water	98	18	Smoking
Hydrazine	Dry Rust	98	18	Small Decomposition
Hydrazine	Wood, Saturated with NTO	98	18	Instantaneous Flame

Fig. 8

Results of Propellant Spill Tests

<u>Propellants</u>	<u>Surface</u>	<u>Temperature</u>	<u>R.H.</u>	<u>Results</u>
Nitrogen Tetroxide	Dry Asphalt	98	18	Rapid Boil Off
Nitrogen Tetroxide	Dry Concrete	98	18	Rapid Boil Off
Nitrogen Tetroxide	Dirt	98	18	Rapid Boil Off
Nitrogen Tetroxide	Dry Painted Wood Surface	98	18	Rapid Boil Off
Nitrogen Tetroxide	Water	98	18	Rapid Boil Off
Nitrogen	Dry Rust Saturated w/HZ	98	18	Instantaneous Flame

Fig. 9

Results of Propellant Spill Tests

<u>Propellants</u>	<u>Surface</u>	<u>Temperature</u>	<u>R.H.</u>	<u>Results</u>
CTF	Dry Concrete	62	13	Rapid Boil Off
CTF	Dirt	60	14	Slight Reaction with small "pops"
CTF	Water	59	15	Several Small Overpressures

Fig. 9 (continued)

CTF	Asphalt	57	16	Vigorous Buring Rapid Deterioration of Surface
CTF	Painted Steel	56	16	Slight Reaction with small "pops"
CTF	Wood	56	16	Smooth and Rapid Burning of Surface

Fig. 10

Results of Propellant Spill Tests

<u>Propellants</u>	<u>Surface</u>	<u>Temperature</u>	<u>R.H.</u>	<u>Results</u>
PB	Dry Concrete	98	17	Instantaneous Ignition <u>In Air</u>
PB	Dry Concrete	85	18	Instantaneous Ignition on Surface
PB	Dry Concrete	70	9	Ignited with Small "pop on Surface after Delay of few Seconds
PB	Dry Concrete	64	9	No Ignition; Finally Evaporated

Large scale spill tests were run to verify and augment data from the small scale tests. Quantities up to 2,000 lbs. were spilled in these tests, singularly and in combinations. The large tests fell far short of their goal in determining the downwind toxic vapor hazard. This was due primarily to deficiencies in the sampling equipment. Despite this, the tests elicited a good deal of useful information per dollar spent. First, we have some real numbers to work from in estimating the blast hazard. Statistically these numbers need verification through more tests and larger quantities. However, they do show that the percent yield is far less than the previously used TNT equivalent table. Also, we have a better appreciation of the fire phenomena resulting from a mixed spill.

Secondly, the tests have pointed out some areas in which additional investigation is warranted, such as obtaining vaporization rate data, a more intensive micrometeorology analysis program to enable an intelligent analysis of vapor diffusion phenomena, and the need for continued study of the whole problem of open air vapor detection.

Finally, I think it has given us a broader picture of the problems involved and the factors influencing test of this type. Certainly future investigations of this type will benefit greatly from our adverse experience in measuring the downwind vapor concentrations.

JOSHUA-ROAD HAZARDS PROGRAM

The Joshua Hazard Investigation Program is an in-house effort designed to evaluate the hazards of transporting lightweight missiles on public highway. For these tests, aluminum, two compartment tanks with a common bulkhead were used. The tanks contained pentaborane and hydrazine. They were exposed to external heating, gun-fire, dropped and punctured. Some fireball data was obtained and fragmentation patterns were noted. Overpressure data was obtained indicating TNT equivalents up to 0.8%. A wet method air sampling procedure as well as direct recording air sampling was used during the tests. The air sampling data was somewhat erratic. It did suggest, however, that fires caused by pentaborane-hydrazine spills are not serious toxic vapor problems. The pentaborane concentrations found within the 50 to 450 ft. downwind radius of the spill area were generally less than 0.2 ppm with a maximum of 0.3 ppm.

Future tests will be similar, except that thixotropic propellants will be used to determine if this technique will reduce the degree of hazard.

VAPORIZATION RATE STUDIES

Hazard classification tests performed to date have shown the fire and explosion hazards to be confined to a relatively small area, while the toxic vapors can travel some distance downwind. One of the more important parameters required for atmospheric diffusion equations and one that is not generally available is emission or evaporation rate. This lack of data, plus the difficulties in measuring the downwind concentrations of vapors, makes the proper assessment of downwind toxic vapor hazard difficult.

The chemical laboratory of DRP is conducting preliminary laboratory scale tests measuring evaporation rates for the Titan II propellants. The test chamber can control the temperature from 55 degrees to 90 degrees Fahrenheit, with relative humidities from 35 to 9 per cent. The air flow can be varied from stagnation to 20 miles per hour. The test area is a six inch square.

The tests have shown that one of the largest variables is the caloric input from the surface to the liquid. This can be varied in tests, but would certainly be difficult to predict or control in the field.

For example, with all other variables (air temperatures, air velocity, humidity) kept constant, varying the surface temperature from 57° to 70° (boiling point of N_2O_4 with an N_2O_4 spill a 5-fold variation in the emission rate may be affected. This variation can be calculated, however, knowing the ambient conditions, specific heat of the surface materials, porosity, etc.

They were also restricted in the tests somewhat in varying humidity by the dew point of the surface material. If we go above the dew point, water will form converting the oxides of nitrogen to nitric acid which throws another variable into the tests.

All of the tests are being run at a constant plate temperature. One set of tests will be run varying the velocity up to 20 MPH at a constant air temperature and humidity. A second set of tests will vary the air temperature with the velocity and humidity constant. These two sets of tests will then be rerun at one or more different humidities. The data obtained to date is as follows:

PROPELLANT	AIR TEMP.	SURFACE TEMP.	VEL.	36 SQ. INS. GMS/MIN E. RATE
N_2O_4	84°F	57°F	500 FT/MIN 5.7 MPH	25 GMS

Additional studies more nearly simulating real conditions are necessary. The "flashoff" or splashoff" phenomena certainly needs investigation.

LIQUID HYDROGEN TESTS

NASA and AFMTC have initiated a program to determine the energy level of explosions involving liquid hydrogen, liquid oxygen and RP-1 fuel. These tests are being conducted at Edwards Air Force Base under contract with A. D. Little, INC. In addition to obtaining blast pressure data, measurements of fireball size, duration and temperature are being made. The small scale spills in this series of tests have been completed and the large scale tests are currently under way.

PERSONAL PROTECTIVE DEVICES AND PROTECTORS

Another area in which the DRP has been active is the development of toxic detectors and propellant safety suits. A project to modify the use of the MSA Billionaire detector for CTF, fluorine, hydrazine, UDMH and N_2O_4 was sponsored by the 6593D Test Group Development. A

contract to develop a direct recording detector has been let to the Armour Research Foundation. A program for laboratory and field testing these devices, as well as the philosophy and practicality of these instruments as area warning devices, has been submitted as part of a larger project for studying occupational hazards.

The development of a propellant safety suit material and a suit design was also sponsored by the Directorate. Firewell Company, Inc., under contract tested a number of materials, including Gray-Lite, Butyl Rubber, Genetron VK, and Teflon. The materials were subjected to fluorine, chlorine, trifluoride, pentaborane, UDMH, Nitrogen tetroxide and hydrazine under a variety of conditions. The most serious test of the materials was its resistance to chlorine trifluoride, fluorine and pentaborane. The tests concluded that teflon fabrics laminated with teflon film provide the best protection. A prototype suit made of a teflon fabric laminated with an aluminized teflon film has been delivered. The suit design included a liquid air pak breathing and ventilation system and a valve-actuated two-way communication system.

PUBLIC RELATIONS IN AIR FORCE NOISE PROBLEMS

Captain Herbert E. Bell, MSC
Hq 2 AF, Barksdale AFB, Alabama

Fellow Engineers: It was rather difficult to know exactly how to analyze this audience. It was even more difficult, after such an analysis, to know what to do with it. Some of you here taught me; others I have tried to teach. Who do you speak to, then? The teacher or the student? After you have listened to what I have to say, you decide!

The U. S. Government has paid millions of dollars to persons who have allegedly lost their hearing acuity due to hazardous noise exposure. This we are all aware of, and since AFR 160-3 hit the field, we have all been trying to do something about this problem. This program at the base is as effective as you, the engineers, make it. The conservation of hearing program, however, is not what I consider to be the subject for this paper. From a public relations standpoint, the problem is one of nuisance and annoyance. This nuisance, accordingly, is not limited to the civilians, but affects the military as well. The military aspects, however, don't cause the difficulty that those involving civilians do, nor the money expenditures.

Since it is not loss of hearing, then how do we as members of the medical service become involved? The answer, I think, is basically for two reasons: (1) we have the instrumentation for measurement; and (2) you know as much about basic acoustics as anyone on your base, and probably more.

It was evident years ago that the jet age ushered in noise as an undesirable aftermath of increased speed and thrust. Airports with 4,000 foot runways would not accommodate the jet age and expansion of facilities and lengthening of runways were necessary accomplishments. With the tremendous move to suburban living, airports in the country were no longer in the country, but practically downtown.

The Doolittle Report, "The Airport and It's Neighbor", prepared under the Truman Administration as a direct result of the Newark Airport difficulty, pictorially illustrates this to be true. The same situation has been true of many of our airbases. The jets fly lower for longer periods of time on takeoff than their prop-driven brothers. The frequency spectrum of most jets is such that we almost have a white noise, comparable acoustical energy with increased frequency. More energy in the frequency range of speech interference, more interference with daily living - interrupted TV programs, telephone conversations and children's rest disturbed. These, anyway, are some of the allegations.

With the passage of the Tucker Act, several years ago, the U. S. Government allowed itself to be sued. Once the word got around, the storm of legal claims began. Within the past two years, in Second Air Force alone, there have been four such legal actions initiated, Barksdale, Forbes, Little Rock and Clinton-Sherman. Claims range almost one million dollars down to \$15,000 to \$16,000.

Let's look at what we must be prepared to do if called upon to assist the U. S. Government in this area. I can assure you we have been and will continue to be requested to assist. I first refer you to the Wright Air Development Division Technical Report 57-10, "Procedures for Estimating Noise Exposure and Resulting Community Reaction From Airbase Operations," prepared for the Air Force by Bolt, Beranek and Newman, Incorporated, an acoustical consultant firm in Boston, in April 1957. The procedures discussed in this report can be used to assess community reactions to current jet operations or determine beforehand what resultant reaction is contemplated. It can, in this respect, be used for master planning purposes. No one has told me how to go about trying to study one of these situations when it is presented. I personally feel that we must conform to the procedures outlined in the Wright Air Development Division Technical Report 57-10. This report considers many variables - some of which are completely subjective. On the other hand, it gives the general operations picture, not for a day, or a week, but for as long as you can dig back and get the data. Normally, it is limited to the advent of the jet age. Consideration is given to frequency characteristics of noise source, the duration of noise, season of the year, time of day (broken down into three periods - 0600 to 1800 hours, 0800 hours to 2300 hours and 2300 hours to 0600 hours), indicating respectively, the working day, the entertaining evening and sleep.

Also included are directions for background noise. These vary from the very quiet suburban or rural communities, remote from large cities, to industrial activity and trucking; normal suburban communities near industrial activities, residential urban communities and noisy urban communities. Another factor is previous exposure and community attitudes - whether the people have had some or a lot of exposure to Air Force base operations with or without good public relations. All of these factors, together with the equivalent continuous sound pressure level (ECSPL) in the 300 to 600 cycle per second octave band, allow one to arrive at one of the following three possible answers:

- (1) Essentially no complaints are reported. The noise may, however, interfere occasionally with certain activities of the residents. (Less than 45 db).
- (2) Some residents within the community may complain, perhaps vigorously. Concerted group action is probably not brought against the authorities, but the possibility of such action exists. (45 to 55 db range.)

- (3) Concerted group action is brought against the authorities. The community action may vary from strong threats to vigorous action. (Greater than 55 db.)

It should be remembered that these db values are not those measured on a sound level meter as an overall, but are adjusted for a continuous equivalent sound pressure level in the 300 to 600 cycle per second octave band.

You say; "We already know the answer before we start; Uncle Sam has been sued." In many cases this is true, but how do we know this is the result of a true problem or whether some sharp lawyer has been beating the bushes for a case. We have discovered by previous experience and can now relate this past with the current on the basis of what should the public be expected to do. This, then, is our stand! Many times, to build a case, you will find all kinds of associated allegations - one man's chickens won't lay; another's cattle won't graze; another can't get help to work in harvesting the crops; another's land has become practically worthless; - you name it, and it's included. For good measure, they even on occasion crank in the black smoke, fumes, and vibration. There are technical reports for reference purposes on some of these allegations also. Technical Report 57-87 deals with the effects of sound of varying intensities on chickens and hatching eggs. Technical Report 59-200 treats the effects of aircraft sound on swine. We can, in these cases, refer to the negative findings of R & D efforts in this area. The Regional Laboratory at Kelly has done work on the Air Contaminant Problem. Their results are that some LOX samples previously analyzed contained more extraneous pollutants than the air in communities associated with air base operations.

It is possible, with the procedures outlined in Technical Report 57-10, to compute the noise exposure in a community from the combined air base operation without actually measuring the noise at the site. This is what the report says, and it can be done; however, in the three cases I have personally studied, the U. S. Attorney won't buy this for a minute. In Federal Court you must be prepared to say, "I stood on, or in, the property in question and these are my findings." After making such measurements, you then go back to the technical report procedure. You have to have been there. Also, I find it impossible to explain to a Federal Judge the detailed procedures required in actual calculations. It's hard enough to define a db so he can understand the meaning.

In May 1960, I was requested to accomplish a noise level study at Forbes Air Force Base, Kansas, involving a Civil Action Suit of Batten et al versus the U. S. Government. There were fourteen plaintiffs, practically involving the entire community of Pauline, Kansas, a small town adjacent to Forbes Air Force Base.

The allegations included almost all of those previously mentioned. In order to give the legal people the numbers they wanted, Bruel and Kjaer equipment at Kelly AFB was obtained. After receiving permission from the plaintiffs and their lawyers, I sat up and ran a complete 24 hour tape with frequency analysis being accomplished periodically. Believe me, this is a tiresome task! The graphic level recorder had to be annotated to identify the noise source; that is, whether it was a takeoff or landing, a run-up, car, train, bird singing or what-have-you. This tape was reproduced and submitted with the basic report. It was possible in this way to get peak levels, durations with time, decay picture, etc. By scaling the time versus level, it was possible to determine what percentage of the day the sound pressure level exceeded any desired value. This was then compared with the operational data averages, maintenance run-up schedules, etc. Measurements were also made inside the house, simulating summer and winter conditions. For this rather active base, there were a total of 169 total operations, takeoffs, landings, run-ups, fly-overs, touch and goes, which could be identified as jet aircraft. Based upon the noise levels created, the levels were above background for less than one percent of the 24 hour day. Total operations in this case compared favorably with the general average per month. It was obvious that the hazardous noise exposure criteria was not exceeded. Maximum noise levels came from takeoffs in the direction of the town. Duration of high sound pressure levels were not such as to pose a major problem in speech intelligibility. The majority of aircraft operations occurred during the normal working day. Based upon sound pressure levels alone, a school bus passing directly in front of the house being studied produced levels higher than a B-47 landing. A train passing in the evening on a nearby track caused an increase above background comparable to a B-47 fly-over during the day. Now, then, do you decide which parameters are important and which are not? It is my opinion, and others, that it is not the level of noise or its frequency composition, but it's association with aircraft in flight which may or may not remain there, or a noise of such prolonged duration that not just a few lines in a television program are missed, but the entire program.

From your standpoint, data accumulation should be complete. You must completely understand what you have presented, and be prepared to answer questions directed to you on the witness stand if subpoenaed to testify as an "expert witness." You, of course, know the definition of an expert witness, I am sure. It is an individual with a briefcase who is more than fifty miles away from home. The experience at Topeka was my first attempt at trying to become an expert, and what an experience! The direct examination by the U. S. Attorney was generally pre-prepared and covered the general findings of the report, how and where it was accomplished, with what equipment, how it was calibrated, and my qualifications. The cross-examinations by the plaintiff's lawyer, however, was a little more exciting: "Do you mean

to tell me the sound level is just as high from a bus passing in front of this man's house as it is from one of those big six-engine jets landing?" After many questions along this line, he wanted to know if I was familiar with the works of Drs. Beranek and Sabine, both of which he mispronounced. His attempt in this respect was to present data not in sound pressure levels, but in phons and sones, a subjective measure of loudness. Since there is nothing in WADD Technical Report 57-10 along this line, or precious-ly little in any Air Force document, I stated I was quite familiar with Dr. Beranek and Dr. Sabine's work, (correctly pronounced) but had tried to keep the report on an objective plane, following procedures established by the Air Force. This line of questioning continued for something over an hour; but, after the obvious lack of knowledge on the part of the plaintiff's lawyer, I sat back and relaxed. The suit was dismissed, but more, I feel, from lack of proof of property de-evaluation and direct aircraft fly-overs than from any testimony of mine.

I returned home (almost missing Christmas) with my \$20.00 per diem while the \$150 per day experts did likewise. Regardless of how you look at it, Uncle Sam was almost \$100,000 better off than he might have been for this Christmas. This whole pitch sounds prejudiced, and well it might be. There was a time when the sound of those jets would have been music to the people's ears, and well it might be yet. Legally, I guess, one must consider which comes first, the chicken or the egg - the residence or the base.

The study made at Little Rock Air Force Base, Arkansas, at a later date, was accomplished in a similar fashion to the one just described. There are, however, several little wrinkles which might be of interest.

Two studies were accomplished at Little Rock, one in April and another in July 1960. Remember, I previously mentioned that the Technical Report 57-10 procedures was the guide but actual measurements were considered mandatory by the U. S. Attorney. This case was even worse. In April 1960, Lieutenant Porter from Barksdale Air Force Base and I were at Little Rock for a week and the wind never blew in the direction which would allow measurements of aircraft takeoff on the property in question. Instead of coming home empty handed, we did what we considered a valid study at the end of the runway where aircraft were taking off. The terrain was comparable, as were all factors, as far as I could determine. After submitting the report, it was decided by the U. S. Attorney that another study would be required on the property in question. The second study was, therefore, accomplished. The plaintiff was not satisfied this time, because, after almost a week, no aircraft had flown over his house, as he put it. After having special aircraft runs made specifically for us to obtain data, it

still wasn't noisy enough for our plaintiff. On the last day of testing, as we were about to fold our tent and silently steal away, Operation "Quick-start" was initiated. One aircraft almost in the wash of the one in front of him. The third aircraft over was a lulu. The old gentleman looked at me from his chair and smiled, "You've got it now, Sonny," he said. Here we had been at Little Rock for a composite of almost two week's total and only on one occasion was the situation what the plaintiff considered bad. Again, I feel it is not the numbers, the levels, etc., but association with closeness and continual interference.

Certainly the Air Force is aware of the noise problem and its effect on community reactions. Air Force Regulation 55-34 in the Operations Series, "Reducing Flight Disturbances that Cause Adverse Public Relations," is designed to minimize the annoyance from Air Force generated noises in civilian communities. I once heard it said that good public relation is the cheapest way to get an additional 5 db attenuation known, and, I believe it!

The Air Defense Command, Office of Information Services, in the early 1950's, prepared a report entitled "Shotgun Wedding" which dramatically depicted how one such noise problem was solved through this medium. The problem started with the transition from P-51 Mustangs to F-80 Jets. People in the community didn't understand the mission and the base didn't understand the community. The noise problem was one of several that had gotten the people down on the Air Force. Land had been condemned for base expansion. The name of the field was almost changed from that of a local World War II hero. F-89 and F86 aircraft replaced the F-80's, etc. Studies of complaints were recorded by time of day, location, sex of caller, and incident complained about. These were plotted on a map and graphed to determine where the major problem lay. From this point, the Squadron Commander and Information Services Officer took over with a full-fledged "get to know us and we you program."

Operations were changed to use runways away from the most congested areas, climb out was as rapid as possible, and schedules of takeoff enforced to conflict as little as possible with children's nap time, which was one of the most consistent complaints. Public relations was the solution here - it prevented the follow-on legal action, which at one point was apparently inevitable, but never came.

Obviously, the cases of which I have previously spoken didn't fare so well. With our bomber runway complex today, fuel and weapon load, many operational procedures possible in the past are either impossible today, or tend to reduce the factor of safety for the crew.

The noise suppressors for commercial jets have already raised a considerable discussion among the Pilots' Air Transport Association.

In addition, and I feel more important than aircraft noise during takeoff, is that of ground run-up during maintenance operations. This type of noise results in the longer duration factor I have previously mentioned. Location of such areas, considering distance, meteorological conditions, directivity pattern, and power settings, is all important. All too frequently in the past, and even today, these factors have not been properly considered. Agreed, it is sounder to consider them prior to installation, and always far less costly. I know, personally, of one base where a Shaw-Estes test stand was located within 900 feet of a new Capehart Housing addition. Early attempts at sound suppression did not prove satisfactory and the stand must be relocated at an expense of approximately \$30,000. In this case it happens to be our own military community, but I am sure there are other bases where it could just as easily have been our civilian brothers. When you review drawings for new construction, and sit in on Master Planning Board Meetings, consider these factors and make yourself heard! If you haven't already prepared a study of your base, using WADD Technical Report 57-10, do so. Make the results known to the Civil Engineer and to your Medical Group Commander. Who knows, this may be the proverbial ounce!

In the remaining few minutes, let's look at another physical phenomena affecting the public in which we should become familiar. The Sonic Boom! In SAC, this has been no major problem until just recently. In ADC and TAC you may already be quite familiar with this subject. The B-58 supersonic medium bomber is currently making its presence known in SAC. At one base in Strategic Air Command, the Air Division Commander is becoming increasingly alarmed at the rapidly increasing public reaction to sonic booms, and also to the problem of health and structural damage. In a period of less than six months, the base legal officer has processed 17 claims. Another 37 claims are currently under investigation. The Governor of the State is preparing to complain to the State Congressional Delegation in Washington. Two of the 37 complaints under investigation come from physicians who allege that the sonic boom has caused two deaths in cardiac patients as a result of the shock. Even more alarm is expressed by the local medical society of reaction of seriously ill patients. One Radio Station has started an anti-sonic boom contest. The Air Division Commander has instigated a vigorous campaign to inform the public by Radio, TV, Civic Group Meetings and even a Mobile Public Address Van in the community.

Much of the apprehension to the sonic boom is derived not from its intensity but from its lack of warning. To assist in the latter, the Command Post at the host base calls the Command Post of the base involved and gives times of B-58 pass-over for that particular RBS. This information is relayed to the local news media.

In July 1960 a joint USAF-NASA Project "Little Boom" was carried out at Indian Springs, Nevada, to determine what damage, if any, sonic booms had on personnel. Two F104-C's and two F105-D's were flown at maximum velocity and at altitudes ranging from 50 to 600 feet, directly over 50 people and assorted equipment and materiel. The booms thus created were felt to be as intense as can be generated by currently operational aircraft. Peak overpressure ranged from 20 to 135 pounds per square foot or 0.14 to 0.94 pounds per square inch. Sound pressure levels, reference 0.0002 dynes per square centimeter were 150 to 170 db. Total time was less than 0.1 second per boom. The shock wave was felt by the entire body very distinctly, and a momentary tinnitus was sometimes felt following the most intense booms. There was no pain, and temporary hearing loss was too brief to measure. Although various types of windows broke, eyeglasses worn by personnel were not affected. By way of contrast, booms experienced by communities from operational flights at altitude, range from well below one pound up to five pounds per square foot. Sound pressure levels range up to approximately 140 db, and time duration is from 0.1 to 0.2 seconds. In a previous National Aeronautics and Space Administration Study in 1959, most observers judged booms of one pound per square foot and above, as objectionable. Complaints were seldom received for lesser pressures.

It was concluded from the Nevada tests that sonic booms of the greatest magnitude possible today cannot incur physiological injury directly.

Relatively weak booms can provoke a true "startle" response. Secondary injury resulting from reactions to the startle is certainly possible, as with a variety of other unexpected stimuli, and is the only real cause for medical concern. The startle response is greatly lessened as people become accustomed to the sonic boom. Individuals may still be annoyed by the phenomenon, but the fact that they identify the sound instantaneously prevents subsequent physiological injuries. This phenomenon must be identified as "The Sound of Security."

PREVENTIVE AND OCCUPATIONAL MEDICINE PROGRAM OF THE USAF

Colonel Lee B. Grant, MC
Office of the Surgeon General
Washington, D.C.

This has been a most stimulating and worthwhile meeting. Our colleagues have described their first-hand experiences in areas of medical concern at missile sit, AC&W sites, alert facilities and overseas operations. The special problems of noise, aviator's breathing oxygen, and aerial spray have been described. Outstanding civilian authorities, including Dr. Frank Princi, Dr. Pat Clancy, Dr. Bernard Tebbens, Dr. George Milly and Dr. Ted Hatch, have provided, and will continue to provide, wise counsel in their various fields of interest. Following me in the program you will hear how the regional environmental health laboratories and radiological health laboratories support the preventive and occupational medicine program.

This meeting has provided an excellent discussion of my activities in the USAF Preventive and Occupational Medicine Program. I will therefore confine my remarks to a discussion of the impact on the Medical Service of the recent reorganization of the Air Research and Development Command and Air Materiel Command into the Air Force Systems Command and Air Force Logistics Command; a new AFR 161-2, "Aerospace Systems Management - Medical," the AFSC Occupational Health Program, and a few areas of special interest not otherwise discussed at this symposium, such as the Federal Aviation Agency, Air Force Study on Jet Aircraft Noise, Tropical Disease Laboratory, the USAF Epidemiological Service, and the DOD Toxicology Program.

Prior to the recent Air Force reorganization, weapons systems development and procurement responsibilities were shared between ARDC and AMC, ARDC having management responsibility for the systems during the research and development phases, and AMC having responsibility during the procurement and site-activation phases. Medically, this led to the sharing of responsibility between Commands for the discovery and evaluation of potential health hazards, performing research in environmental health areas where data are needed, developing engineering and medical control procedures, evaluating technical orders, manuals and pamphlets delineating engineering and medical requirements.

With the Air Force reorganization, management responsibility for the weapons systems no longer shifts between commands, but remains with AFSC throughout until the weapons system is turned over to the using command. Medical responsibilities likewise no longer shift between the two commands. This is not to say that other Commands do not have the responsibility for contributing to the aerospace system development. The new AFR 161-2, "Aerospace Systems Management - Medical,"

in fact delineates the medical contributions expected from these other Commands. However, it does mean that AFSC has the responsibility for delivering a weapons system to the using Command that has incorporated the following:

1. Consideration of human efficiency in the medical aspects of aerospace vehicles and work place environments, including missile launch complexes.
2. Survival and rescue techniques.
3. Medical aspects of defense against nuclear, chemical and biological weapons.
4. Methods for detection, measurement and control of adverse chemical, physical, and biological agents in the total Air Force environment.
5. Regimes for periodic physical examinations.
6. Techniques for the diagnosis and treatment of personnel who may suffer acute, subacute or chronic effects of exposure to chemical or physical agents.

Medical areas of research and development must be scrutinized at each phase of the aerospace systems development. Recommendations for developing new knowledge, techniques, tests, or standards will be made by all echelons of the USAF Medical Service in appropriate aerospace systems documents. Areas of responsibilities for medical input include the following:

1. The Surgeon General will assist in the preparation of medical portions of the aerospace systems documents for which Hq, USAF has primary responsibilities, and also monitor the systems package program continuously to insure that adequate medical considerations are included. Program documentation responsibilities are spelled out in the AFR 375 series and AFR 80-2.
2. He will advise the Deputy Chief of Staff (Research and Technology), and the Deputy Chief of Staff (Systems and Logistics), on medical research requirements necessary to support aerospace systems, and on the delegation of medical research project tasks and funds to major air commands in accordance with appropriate regulations.

3. He will coordinate medical research matters in support of the aerospace systems with other service and federal agencies in order to avoid duplication of effort, resources, and facilities.
4. He will establish policy and review formal medical training programs for medical and nonmedical personnel supporting the aerospace systems and, finally, he will review quantitative and qualitative medical personnel requirements for the new aerospace systems support.

The Surgeon, AFLC, will also prepare medical portions of aerospace systems documents for which AFLC has responsibility. He will further develop procedures designed to maintain surveillance of the work environment and detect evidence of adverse effects of environmental exposure, as well as evaluate and recommend suitable engineering and medical procedures for the control of environmental health hazards and the diagnosis and treatment of personnel who have been affected by environmental exposures. He will advise and assist in preparing necessary manuals, technical orders and other publications and review technical orders and other publications as may be prepared by a contractor to insure that medical aspects have been adequately covered.

The Surgeon, ATC, will advise and assist the Commander of ATC in developing and conducting formal training programs for medical service personnel to provide them with an adequate knowledge of potential health hazards, including the methods of detection, evaluation, diagnostic procedures, and therapeutic measures. He will prescribe the medical training necessary to give nonmedical students enrolled in ATC technical training courses a working knowledge of the health hazards and preventive measures needed for personal protection. He will prepare training manuals as prescribed by Hq. USAF for the support of aerospace systems from technical information received from AFSC and AFLC. He will review training manuals and courses of instruction for nonmedical personnel to insure that current information on medical aspects of the weapons is included. He will participate with ATC staff agencies in developing medical portions of qualitative and quantitative personnel requirements information.

The Surgeon of the using Commands will develop the detailed manpower, organization, materiel, and facility requirements of the medical support elements. He will provide consultation services to Command representatives in the systems program office or other responsible organizational elements and, finally, he will conduct such special on-the-job training as may be required for medical support of the particular system used by the Command.

In addition to the responsibilities I have spelled out above for AFSC, the Assistant for Bioastronautics of AFSC will monitor the progress of aerospace systems development continuously to insure that the pace of medical research accomplishment is consistent with the hardware development, and he will develop and make available to the Surgeon AFLC, Surgeon ATC, and other research and training agencies, as appropriate, toxicological data and other health hazards information. He will make available medical service personnel to the systems program offices to assist in evaluating and preparing required research and medical support requirements. He will also prepare the medical portions of aerospace systems documents for which AFSC has primary responsibility.

To meet these increased responsibilities, AFSC is in the process of strengthening their Occupational Health Program. On 28 June 1961, Hq. AFSC issued the Command Occupational Health Program policy which assigned the following program responsibilities:

1. The Assistant for Bioastronautics, Hq. AFSC, has the over-all responsibility and will exercise approval authority on major policies relative to the program.
2. The Command Surgeon, AFLC, is assigned staff management and coordination responsibility for the program.
3. The Deputy Commander, Aerospace Systems is responsible to insure the Occupational Health Program is integrated and coordinated with the Aerospace Systems Program.
4. The Staff Surgeon of the Deputy Commander, Aerospace Systems is responsible for performing those activities necessary to carry out the Deputy Commander, Aerospace Systems responsibilities, and especially to see that adequate medical support is provided the systems program offices within the Ballistic Systems and Space Systems Divisions.
5. Lt. Colonel Bob Shirley, with Lt. Colonel Juan Ramos as his engineer, will carry out the responsibilities for the Assistant for Bioastronautics and the Surgeon, AFSC. They will assure that required environmental health data is developed throughout the weapons system development cycle, both at contractor plants and AFSC bases. Further, they will see that the data is integrated and disseminated throughout AFSC and to other major commands having an interest therein.

The occupational medical programs are being strengthened at Cape Canaveral, Edwards and Vandenberg AFB's, to provide adequate capability to obtain environmental data, as well as to provide health protection aspects of the program. At Cape Canaveral, Pan American has developed an Industrial Hygiene Laboratory to support the day-to-day activities of their Industrial Hygiene Engineering Staff. Captain Kittilstad, at Edwards AFB, has been assigned to the Staff Surgeon, Deputy Commander of Aerospace Systems, in Inglewood, California, with duty station at the Missile Test Facility at Edwards AFB. Another Engineer will be similarly assigned to Vandenberg in the near future.

These assignments, along with the recent arrival of Lt. Kingsley at the Inglewood complex, will provide a strong industrial hygiene engineering capability to supplement the medical capability provided by Colonel Nuttall and Lt. Colonel Peterson. As you can see, much environmental health talent is being concentrated at Inglewood because it is here that the Systems Project Offices are located for the missile and space systems. These offices have the complete management responsibility for the weapons system until it is delivered to the using Command. Medical support to these offices is essential.

The Aerospace Medical Laboratory, Wright-Patterson AFB, is enhancing its capability to provide acute toxicological data. Sub-acute and chronic toxicological studies will be handled through the tri-service toxicological facility at the Army Chemical Center, or on contract with civilian research centers as part of the DOD Toxicology Program.

There are plans presently being implemented to bring the Aerospace Center at Brooks AFB into the Systems Command. Under this concept a separate division will be formed within AFSC which will bring together all of the Air Force medical research effort.

With these additional capabilities, the Air Force Systems Command will be able to discharge the new medical responsibilities assumed as a result of the reorganization. AFSC will continue to look toward AFLC for laboratory support from the regional environmental health laboratories and radiological health laboratory. AFLC will continue to maintain its responsibilities for the Air Force Occupational Health Program as set forth in AFR 16-20. There will be the utmost need for close cooperation between the Systems and Logistics Commands to insure an adequate Occupational Health Program within the Air Force.

Let me digress in the remaining portions of my presentation to discuss some other subjects of the Preventive and Occupational Medicine Program that may be of interest to you.

The Federal Housing Administration, acting upon recommendations of the Federal Aviation Agency, that land subject to noise in excess of 100 decibels would not be desirable to be used for residences, decided not

to insure home loans on houses located on such land. The Federal Aviation Agency and the Air Force initiated a joint study program to provide noise contour data on both commercial and military jets for use by the Federal Housing Administration. The Regional Environmental Health Laboratory at Kelly AFB will develop the data for military aircraft. Most of the studies will be done at Kelly AFB on aircraft locally available; however, it will also be necessary to go to other Air Force bases to study aircraft not available at Kelly. Hq. USAF has requested the cooperation of all the Commands in these studies. It is anticipated that the study will be completed by February of next year. The information developed from this Air Force study will be made available throughout the Air Force.

The establishment of a Tropical Medicine Laboratory at Clark AFB, Philippine Islands, is presently under consideration. This laboratory would be independent from the Hospital at Clark AFB, and would function as part of a USAF Epidemiological Service, plans for which I will describe in a few moments. This laboratory would have both a research and teaching function. Present plans include a staff of approximately 12 persons. Spaces for manning the facility would be obtained from those occurring as a result of closing of other medical facilities. The laboratory facilities would be placed in vans which would eliminate new construction requirements, and also permit greater mobility. No date has yet been firmed up as to when this laboratory may be established.

Thought is being given to a reorientation of the mission of the Epidemiological Flights, as well as a reorganization of these flights into a USAF Epidemiological Service. It is envisioned that this service will also include the Epidemiological Laboratory at Lackland AFB as well as the Tropical Medicine Laboratory I just discussed. The service would be under the technical guidance of the Office of the Surgeon General. The officer in charge of the service would probably be the Commander of the Epidemiological Laboratory.

The establishment of the service will relieve the flights in the role of providing routine preventive medicine support to the bases and commands. It will require that they accumulate and analyze epidemiological data, recommend environmental control measures, provide preventive medicine consultant services, and collect medical intelligence data. The service will have the capability of providing special epidemiological investigations throughout the world wherever Air Force personnel are either stationed or are anticipated to be stationed.

Project TORES is a Department of Defense program under the supervision of the Advanced Research Project Agency. The program provides DOD funding for toxicological investigations and designates a tri-service toxicological laboratory service at the Army Chemical Center, Maryland. The project is presently funded for one-half million dollars for FY 1962.

Of this, \$200,000 is for in-house military chemical program at the Army Chemical Center, while \$300,000 is available for outside research contracts. The Advanced Research Project Agency has established a Steering Committee made up of members from each of the three services. The function of this committee is to review projects submitted by the three services, to set priority on work accomplishment, to determine whether the work should be done in-house or on contract, and to determine whether or not the projects are of interest to all three services. Only work of interest to all three services will be performed under this project, other work will be accomplished by the individual services.

In closing, I would like to emphasize again the importance of the contributions of the Sanitary and Industrial Hygiene Engineers to the USAF Occupational Health Program. A team approach is required in all phases of the Occupational Health Program. The Engineer is a vital part of that team. His development of essential environmental data supplements the medical data obtained by the physician. This combined approach determines whether a hazard exists and the extent of the hazard. His development of engineering control measures again supplements the medical control procedures instituted by the physician. This combined approach provides a healthy working environment for all Air Force personnel.

~~-----~~ PANEL DISCUSSION

LABORATORY SUPPORT OF THE USAF PREVENTIVE
AND OCCUPATIONAL MEDICINE PROGRAM

Moderator: Lt Col C. C. Dills, USAF, MSC, Hq SAC

Panel Members:

Captain Charles H. Powell, USAF, MSC
Regional Environmental Health Laboratory, McClellan AFB

Mr. Edward Poth
Regional Environmental Health Laboratory, Kelly AFB

Captain C. A. Markarian, USAF, MSC
Radiological Health Laboratory, Hq AFLC

MR. EDWARD POTH:

One conclusion regarding the lab has been a lack in communication. This is one of the real problems we encounter, not only in our dealings with people in the field, but it is pretty evident that the problem exists also with technical speakers, because you've heard quite a number of them voicing techniques here where they have used examples. For instance, you've heard about the horses. This sort of presentation has a lot of advantages. First of all it allows a speaker become an expert without having slides, and probably the sneakiest thing about the whole thing is that it transfers responsibility from the speaker to the listener, for understanding what he is saying, because if the listener can't understand the simple example that is given, he surely can't understand the technical data he is presented.

I would like to set the example that we are going to use this afternoon and liken the system of the laboratories to a corporation, wherein the laboratories or the plants and the engineers in the fields are the stockholders, and also by virtue of their locations, also the users of the products. Perhaps the directors would be the Command Engineers; maybe the Chairman of the Board is perhaps somebody in the AFSC Surgeon's office, or Surgeon General's office. At any rate, this lends itself very well as an explanation of how this thing should operate. In the following this theme, it relieves me of the responsibility of doing nothing more, as a plant manager, than to tell you what we've done, because the responsibility lies with you stockholders to tell us what you would like to have us do.

I don't need to tell you what we are capable of doing, because this is in our little brochure AFR 160-15, and in some of our publications from the laboratories we have told you what we are doing in the way of services, and I think most of you know this. The thing that you probably don't know with any intimacy at all is the strength of the laboratories, how many people we have and what we have been doing for the last four or five years.

I must speak for Kelly, because I know nothing of the operations here at McClellan, but I'm sure that they are quite similar; the physical plants themselves are very similar. We have the same type of equipment, with the possible exception that we have an emission spectrograph and they have an X-ray defraction

instrument. This is probably the major difference. Back in 1957 the laboratory at Kelly went into operation. The laboratory at McClellan was already in operation and had been for a year or so. We had the advantage of the experience of these people in quite a number of things, primarily that of selecting equipment which was applicable to this sort of work, and avoiding some of the equipment with which they had been having trouble.

In 1957 we started out with one person as the head of our laboratory, Mr. Bryant, who is now our chief chemist. He gathered equipment and people around him, and in 1958 we had eight people. This was the first real year of partial operation. During this year he had enough information to set up some work standards, work units whereby he could judge what his people were doing.

We established a work unit measurement system which applied to each individual in the laboratory, and this included clerks, dishwashers, technicians and chemists. A work unit was defined as anything that would stand alone as a unit as a finished, complete project. This might require five minutes to complete a work unit, or it might require five months or five days or any given length of time, because the nature of the project would determine the time it took to complete it. On the overall basis, though, we found that each individual could complete one and one half work units per day. This turned out to be a very good estimate based on our definition. For 1959, which was our full year of work with the present number of 12 people, we found that this checked very closely.

We had a lot of work, what we called internally generated work, which was that of preparing procedures and trying to adapt other procedures to some of the work we were getting from the field, and simply letting the chemists and technicians in the laboratory learn the work, because these people were not industrial hygiene chemists, they were simply chemists taken from the professions and trained, and it took about a year and a half to train them.

In 1960 we began to find out what these people were doing, what our work loads were and this type of information. This will be the report I'll give you as a report to you "stockholders" of what we did in 1960. We have some data on 1961, but it is not complete. Actually, in 1960 we had about 4500 incoming laboratory work units. If you will calculate on the basis of twelve people doing one and one half work units, we could complete about 4000 work units in a year's time, based on 230 work days a year. This is the way it turned out. At the end of 1960, we had 376 work units (about 10%) of work not completed that had to be carried over into 1961, so our

estimates were pretty good. The people were operating at an efficiency scale of about 103%. This looked fine on the basis of this 10% overload, and to stay current it required four more people.

In 1961 the story is a little different. We still have twelve people. To date (October) we will have already over 4,000 work units of work that have come into the laboratory. Our so-called efficiency index per person has gone from 103% to 120%. Don't let this fool you. This isn't efficiency; this is simply substituting quantity for quality, and this is already in evidence - you can see it in some of the mistakes we made. We expect, on the basis of our present experience today, to be about 30% behind at the end of 1961. We need to keep current now, about eight more people. I know there are a lot of questions that you would like to ask about the specific operations, and Captain Markarian has to say something, and so does Charlie, so I'm going to stop right here and turn it over to them.

CAPTAIN MARKARIAN:

I'd like to cover just about three areas of our program; one is the general overall mission, a quick look into our program; secondly, our new projects that will come about in the next two months. I felt that this would be a good opportunity since this project is coming into effect, and all the engineers from practically all the Air Force Bases that are here can assist us tremendously in making this a satisfactory program for the Air Force.

As you all know, the mission of our laboratory is to perform necessary bioassay analyses in film badge services to support the Air Force Radiological Health Hazards Service Control Program, as outlined in AFR 160-134 and AFR 160-15. The service includes film dosimetry and neutron dosimetry. The laboratory provides all the necessary materials and supplies to operate an effective monitoring program. Upon request, the bioassay area, the laboratory, will perform radiochemical procedures for the detection and quantitative analysis of radioactive materials in body fluids and environmental samples. We have a fairly good set-up as far as radiochemical procedures are concerned. What we have done to help establish this laboratory on a crash program is to plagiarize their best procedures from all the National Laboratories. We went to each National Laboratory for two or three weeks and took their best procedures and installed them in ours, so we can actually say that we have an excellent radiochemical procedure in our laboratory.

We can do just about any examination within reason, and of course, the examinations that we do perform are sufficient for the Air Force requirements. The professional personnel in our laboratory also act as consultants to the AFRLC surgeons in matters pertaining to Radiological Health and, upon request, we will perform radiation protection surveys and consultation visits to the installations throughout the Air Force. Also, we perform X-radiation surveys at Radar sites as they become operational. This is being broken down to area regions which is a little more practical, in that we are away from our home station quite a bit.

We also have within our groups special projects both in bioassay and film dosimetry - these one of a kind of situations. They sometimes tend to go into the R and D program, which we want to stay out of completely, but we do help out if we can and, if not, we send the people elsewhere to get this work done.

What I want to present to you is the future capabilities, or improvements that we are about to make. At the present time in our film dosimetry program, we have certain variable errors in our film badge processing and evaluating. We have the innate error of film plus the variable errors of the humans doing the work. One way that we decided to get around this was to eliminate the human error and put with the innate error. From this approach we purchased an automatic processing apparatus, an electronic computer for our electronic detrometer in a computer form, plus IBM equipment. The film will be processed automatically, dried, read in our densitometer, converted to a dose of integrated densities, and punched on an IBM card. Now this all sounds simple but, to get to this point, here is what we had to do, and this is where we are going to need your assistance and need it badly to make this successful. We sent out a survey some time ago on the number of people who were being monitored, the number of film badges on hand, and the anticipated increase in fiscal year 62. I didn't expect it, but we did get about a 99% return from all Air Force installations throughout the world. This was excellent. When we received this information, we sent out the second survey to register each individual who was working in an area of ionizing radiation or working with radioactive materials. We have a registration or a master card on each individual. The purpose of this is, right now we can't follow individuals from base to base. If Joe Blow is at Base X and goes to Base Y, we can't follow him. We receive on an average of ten or twelve letters a week from civilian organizations wanting a total of accumulative dose on individuals while he was in the military. Well, we can't provide this at this time unless we are provided the following information: his name, the base he was located at, and the year he was located there, only that; but this takes almost eight hours per man to locate, so it takes a lot of time.

Also, because of certain over-exposures, the AEC has had a regulation to the effect that a man should be followed after he is overexposed because of a bi-product source for a period of thirteen or fourteen weeks, or even thirty days. We can't do this, either. If the man is reassigned, he is lost; so the point that we are making is that if we go into this registration form and which is now about 90% complete, we will be able to have a master card on each individual; we will be able to follow him from base to base. If the base is not doing their job, we will still be able to pick up this man, because what we are planning to do is to send out annually 32 IBM cards per person. This is what it takes to monitor a person on an annual basis. When the bi-weekly film is picked up and sent to our laboratory for processing, the film is accompanied with this IBM card. If the man isn't registered,

he won't have a card. If he comes in newly assigned, he will have to re-register. If he does not do this, he will not have a card, so no matter what happens, we'll catch him, and when we do catch him, we will be able to take his master card and put it in the right area. The big problem here, of course, is twofold; first, the re-registration of an individual being assigned from Base X and Base Y, and second, the use of the film badge holders.

At the present time, we have made a transition period overseas on replacing all the metal badges that we had in effect. They now have our new plastic holder which is compatible with our electronic densitometer. The metal film badges are not compatible. We are not going to use them, and those who are packrats, and we have a lot of them, who are still using them even though they have the new film badge plastic holders, when we go into this automatic processing, you are going to be out of luck, because we won't be able to evaluate it. So I suggest to you when you get these new plastic film badge holders to return your metal holders, as they are not going to be worth a darn. We have replaced all overseas bases with the new plastic badges. Stateside, we have replaced approximately twenty-two bases; next month or at the end of October, we will make a transition in the States and replace every one of the old badges. When you receive these badges, there will be instructions with them to tell you when to start this program. Now we already asked these bases who have these new film badges to start on the first day of the month through the 15th and begin their changeover on the 16th to the last day of the month. This gives us an even flow of work. Instead of having valleys and peaks, this will give us an area where our flow of work will be constant and be of the same amount, so you won't be busy one day and doing nothing the next day. In November or early December, we will start receiving your IBM cards. If you have, say, 50 people that you are monitoring on your base, you will get something like 1500 IBM cards. There are only three things you have to do on the IBM cards. We are eliminating Form 1523, the form that we use to ship the film badges back to us with all the information on them. You don't have to do this anymore. There will be three areas. The date that you gave the film badge to the individual who is being monitored, and also another square where you just put in the date of the time you picked it up, and that is all. Now there is one thing I do urge you to do for us is, if you will, which will increase our efficiency (and if we increase our efficiency, you are going to increase yours), and that is to put this in numerical sequence when you ship it to us. This is all we ask. If you can imagine getting information or getting materials from 350 Air Force installations and putting this in numerical sequence every time they come in - well, this is a

big job. We just don't have the people to do it, but you can help us by doing it for us, if you have 25, 30, 50, whatever it is. This, we hope, will start 1 January. We have some of our IBM equipment now. We are testing it out, and we are sending people to school to become efficient in this program. When we do start this in January, if you do have any problems, and you don't quite understand our instructions, write us a letter or call us. Our instructions are purposely written so an Airman basic can understand them. For instance, we've been having a problem unloading our film badge holders. If the film badge holder is loaded with our dosimeter film and it's not properly inserted, we cannot evaluate the film. What we did to test this out to see how explicit our instructions were was that we made a little drawing showing where the film goes, how it goes, and how to insert it, how to take it out, and the language is real simple. I urge you, when we get this information to you, read it and pass it down to your subordinates. Also in November, we are coming out with a brochure which will clarify quite a bit of information that perhaps some of you are not aware of. This brochure is about fifteen to twenty pages long and gives you all of the details as to our services that we can provide you, primarily, and how to go about getting it if you are not already obtaining our services, and extraction of all regulations in the back of the book indicating where you may go for information. This took quite a bit of time to do. We were fortunate in having a reserve officer on active duty for two weeks, and this is one of the projects that we gave him, and believe me, he did a thorough job, because he came up with regulations that I had never heard of that referred to the ionizing radiation film badge and such a program. Now, regulations AFR's 160-134, 160-132 and 160-15 are all out of date as far as I'm concerned. We have progressed to a point where we outdated our regulations. Now we hope within the next two months we will come out with a revised AFR - at least we have plans for a revised AFR; I don't know how long it's going to take to get down to the operating level, but this will be in detail. We hope that if we don't go into an AFR, we will go into an AFM, giving you details on everything that we do, so that you can do a better job at the base and increase your efficiency as well. There are three things that I would impress upon you, and if I can accomplish this and clarify these three points, I will call it very, very successful. I've already mentioned them but I want to repeat them just for your edification.

1. The loading of the film badge; this is very important.
2. Completing accurately the registration form on all your personnel.

What has been happening on this is that date of birth given as "July 1961" or June 1960." Quite young, I'd say! This whole program is based on identification of Social Security numbers, since everyone, civilian and military, has a Social Security number. Identification will be made by Social Security Numbers, but we get many, many registration forms which do not show Social Security numbers and we have to send them back, which increases our administrative load.

3. Newly assigned personnel, such as Joe Blow left Base X last week. They had just made out a form, and he comes to the Base Y the following week on a PCS, - have him make out another one.

There are a few things that I want to clarify that were discussed yesterday on the neutron badges. We have neutron badges; they are modified ORNL badges, and we received them about two weeks ago, and you will find one area here that's going to cause a little conflict, but there is no legal complication here. We used the AEC mold. We got their permission to use their mold and have them manufactured by the local patent button company down in Knoxville. Well, they made them for us, all right, but on the back of the badge you will find "property of the United States Atomic Energy Commission; if lost, drop in a mailbox." There is not much we can do about this. There is a time limit, and we can't send them back and not accept the item, because we need them for Sundance next month. But if you see that on these, don't get excited - they belong to us; we paid for them. They cost around \$14,000.00, so they are ours. Another area is, along with the neutron badges we do have the associated equipment to read neutron badges. I believe that yesterday there was a comment that this equipment should be purchased, but we already have this equipment and it is functioning.

Another thing that we are going to do with our IBM equipment; we were fortunate in getting all the necessary machinery established in our laboratory. It was a long fight, but they decided that yes, the IBM equipment does belong in the laboratory and not over in the Base Staff Services, and we go up there with a truckload of cards all the time, so we are going to use it in our library program. We received reprints from all of the National Laboratories and all the other research organizations and what have you, and it is impossible to screen all reprints and articles. So we are going to set up an IBM coding system and a logging system. If we want to know about whole body counting, we just push the card into this IBM machine and immediately have complete reference data and what volume we are holding, so we can go right to these articles instead of spending two hours trying to research it.

We can just take an IBM card and come up with this information. So we will be able to provide some library service to you as well. We can tell you where to get it, and the information that is contained in it. This won't be for a while, but it's one of our projected future improvement areas I refer to.

Just for some statistics as far as cost is concerned, in dosimeter film last year, to have this monitoring program in the Air Force, we expended something like \$25,000.00 for film, and this does not include the film badges or the associated equipment, just the film itself. This is a lot of money. However, when you actually stop and think about it, it's nothing. It's peanuts. The medical-legal aspects of this whole program is worth the \$25,000.00 expended, and if it goes up to \$50,000.00, it's still worth it. In the future, there can be a lot of claims against the government which will go up into millions of dollars, so a few dollars expended to prevent this, I think, is a good preventive medicine. I did have other statistics here on the amount we processed and the increase in workloads, but that is extraneous at this time. There is one thing that I'm very happy about, and I agree with Colonel Korn on his statement about fighting for spaces. We were fortunate back in February. We put in for some spaces as effective 1 January 1962 to increase our personnel to 100%. These personnel will be coming October 15th, so we will be able to even give you a better service. What we are striving for is 24-hour service. I don't know if we can do it, but we are going to try. In other words, 24 hours after we receive the film, you are going to get answers, not three or four weeks later like you are getting now. I'll entertain any questions you might have, and I'm sure there are plenty.

CAPTAIN POWELL:

I just wanted to give you some idea of the areas of not only the McClellan Laboratory, but also of the Kelly Laboratory. We have a much larger geographical area; fewer bases, but longer distance to travel. I think our bases run sixty-five or seventy, and Mr. Poth just told me that they have a little over a hundred in their area. There are a couple of things that I would like to discuss, but most of the things that apply to Kelly also apply to McClellan. I do feel that there has been a little misunderstanding among some people. They say Environmental Health Laboratory. This means to them a group of chemists at McClellan and Kelly, and a great many people don't realize that both the Kelly Lab and the McClellan Lab also have a comparatively large and well-staffed engineering service.

At the present time we have four Sanitary Industrial Hygiene Engineers assigned to the regional office as well as a number of Preventive Medicine technicians. I think this ought to be brought out so that you realize that we have not only chemists, but also engineers, and we even had a statistician on our staff for a while.

During this panel discussion, one of the main questions which should be answered is, are we really worth the money that we are spending? So I took a hard look at how much money we spent both for salaries, chemicals and equipment, and for the laboratory alone, not including the base section which is also associated very closely with us. The bill comes to about \$75,000 a year both for salaries and equipment. This may seem like a large expenditure, and I sat down to start figuring up how much it would cost if Kettering Laboratory or other consulting engineering groups were to do the work for us, and it didn't take me very long to surpass that \$75,000.00 figure. By the time I had figured the cost of lead analysis and engineering consulting services, I passed the \$75,000. The areas that I calculated up take approximately 30 to 40% of our actual working load. The rest of the time with other types of analyses and engineering problems that we have within the laboratory itself and working on special projects such as reported by Captain Smith this morning on the Titan II system, and as Mr. Dankman will report this afternoon on the evaluation of air sampling devices. Now you can put a price tag on this kind of work, I don't know. Our staff is just about the same size as the Kelly Laboratory. There is very, very little difference. We are staffed, primarily I should say, predominantly with military type personnel, while they have a great many more civil service employees at Kelly, which

does make a little bit of difference in our operations. One of our biggest problems is influx of military personnel, and then there are reassignments, and we have a constant retraining program which I don't think they are faced with quite to the extent at Kelly that we are here. One advantage of personnel turnover is that new people bring new ideas which is always a healthy scientific atmosphere in which to work.

I just wanted to bring out these few differences. I think everyone has a pretty good idea of the type of work that we do both here at McClellan and at Kelly. Mr. Poth came up with some data a while ago that he was having something like 90% participation of the laboratories in the Kelly area in their program. This is almost exactly the same as we have here. We do find that we have to go out and beat the bushes occasionally. We have a turnover of engineers at the base, and it seems that the old one never tells the new one about us, and we have to get a letter off to him or go out to visit him and re-establish communications before he's aware that we are even in existence. This has been a continuing problem for the last ten years. This is basically all that I wanted to contribute at this time. Do you have anything that you want to say, Colonel Peterson?

COLONEL PETERSON:

We had a little method in our madness in selecting the McClellan Field for this particular symposium, the purpose being that among other things, of course, is that it would afford an opportunity for you to see one of the Preventive Medicine laboratories the Air Force operates. I've heard on many occasions, especially among the younger engineers, the question, "What does this laboratory do? Where is it located? What good does it do me, etc?" And I think this is the best opportunity we could afford you to find the answer to that question. I would like to emphasize that the laboratories are nothing but tools for your use, and I invite you all to use them. We have plenty of work to do. I'm not necessarily soliciting work, but I hate to see the engineers neglecting problem areas at their base where support from the laboratories would give you better answers. We will try to give you the best possible service we can with the people we have available. One of the points that has been emphasized, and I would like to emphasize again, is that we are not just an analytical chemical laboratory facility. Engineering consultant service is also available to you. We have technical information we can provide you; we have tools, field laboratory equipment and sampling devices we can loan you. We can help you calibrate equipment. We would prefer, in the case of equipment calibration, and I'm talking now about equipment you use pretty strictly in Industrial Hygiene, we would prefer that you bring this equipment to the laboratory so you can gain more familiarity with the use of this instrument and learn more of its limitations and capabilities. I would also like to mention that in addition to the laboratory here at McClellan, the one at Kelly and the Radiological Health Laboratory at Wright-Patterson, we also have a very well equipped laboratory in the European theater, and for those of you who might wind up in Europe some day, keep this in mind. The facility is there for you to use, and I invite you to use it.

COLONEL DILLS: Are there any questions from the floor?

COLONEL C. BOVEE:

I have a few questions which I think can be answered almost "yes" or "no" in Environmental Health and one for the Radiological Health Laboratory. One was just mentioned by Colonel Peterson about the equipment. Most of the engineers have an ECL type of equipment. I think the instruments we are probably going to have are going to increase in number and complexity in the future. At the present time, we have no good way to take care of repair required other than to ship the thing back to the manufacturer and lose a lot of time and a lot of effort trying to find out what to do with it. Could we possibly include an equipment repair section with the calibration service in the event electronic circuits get out of order. A little bit more -- the PhEL labs. Of course, we've got those at every base, but they support the flying mission of the base and are not able to take care of 80% of the type of equipment that we have; the octave band analyzers, noise level meters, exposimeters, that type of thing. When a circuit is out, well, unfortunately a lot of times we purchase a new instrument.

COLONEL PETERSON:

At the present time, Cliff, we are not staffed to do that type of work. We do have in the McClellan laboratory here one electronics technician, Mr. Brandt, who takes care of the equipment that we use in the laboratory, and on a courtesy basis, he does some repair of instruments that people bring in for calibration. But we don't have the equipment, and we don't have the time to take care of that at present. If this is a big problem and the laboratories at the bases can't handle it, I would suggest, at least for the time being, that you send it back to the laboratory. Meantime, we can consider this a problem, and if there is a real requirement for this, we'll consider the possibility of doing it.

COLONEL BOVEE:

Well, let's look at the requirements. You've got an ECL out; a SLOE is out authorizing the equipment. The equipment is put out into the field, and there is no maintenance capability for it. We just have to find out who manufactured it, get in contact with the manufacturer, find out where to send it and get it repaired, and this usually throws that instrument out of commission for a long time. I think it's something we might think of. The other question I had for the Radiological Health

Laboratory is, most of your installations that you are monitoring on the film badges are fixed installations. They have an X-ray or something that stays in there year after year, and you keep monitoring the same place all the time. In the Air Defense Command we use in the Radar sites and quite often we shift sites, and the question comes up as to which site is going to be monitored. More and more this is going to be true, because right now we are in the process of changing radar equipment throughout the Command. This is a constantly changing problem, and I'm not sure that I could tell you today from my position which of our sites are being monitored or whether they are the right ones that should be monitored. I know you people follow direct communication channels between the base and yourselves; we don't go through the divisions; we don't go through the headquarters. The Headquarters and the Divisions sometimes aren't aware of just what thing is current. This is fine. It expedites the service, and I think it should be continued, but I think we should on a policy basis coordinate with the Headquarters concerned whenever there is a change on something to be monitored.

COLONEL DILLS:

May I put an answer into this? Some months ago we had Colonel Lou Kossuth come into Logistics Command. There was a problem back in the numbers of film badges that we were processing, and I think at that time a request was made that the Air Defense Command select the sites at which we would monitor a certain number of each type of radar that you had. The program that has been set up has been established on that basis.

MR. ROBLES:

As a matter of information on this repair and calibration, Dayton Air Force Station has the biggest mobile repair and calibration teams within the Air Force. I'm sure if there are any of you that have large calibration problems, they will be glad to help.

COLONEL BOYSEN:

Well, this is in part, I think, where some of the PMEL laboratories are operating from, and they have been in a process of making a study to determine numbers and types, and whether or not they can afford to get into some of this calibration, and this is the reason there is a "gray area" here at this point in time.

CAPTAIN OWEN KITTLSTAD:

Going back to Mr. Poth's original concept earlier when he was talking about the corporation, I don't intend to sound like the disgruntled stockholder in this corporation, but due to the number of things that have been said today which are new to me, we've taken on a considerable load in AFSC, as you might suspect. I might preface my remarks here a little bit to say that I have discussed this thoroughly with Mr. Poth and Captain Powell, and they are in complete agreement, or somewhat in agreement, that my complaints in this area are somewhat valid. I don't say this to criticize, but as I lay this before the people that are here to see what can be done about it, I charge that I don't think the Environmental Health Laboratories as they are now manned and as are now established can support us in the research effort that we have in AFSC. Just to cite a couple of examples of what I mean, in June we fired the largest beryllium engines that have ever been fired in the free world today. This was not a very big job, but based on this, we thought we would try to gather the maximum amount of data that we could from these tests, so a rather elaborate program of air sampling was set up, and through a series of diverse channels, wound up with a recommendation that we do send these samples to the Regional Environmental Health Laboratories for analyses, which we did. Four months have passed, and I still don't have all the results for these tests. Now, we can't operate on this basis in AFSC. We need data, and we need it fast. I could cite another example that goes back even farther, which happened probably about a month or so after I got transferred to Edwards. When I wrote to McClellan and asked them if they could provide me with some sampling procedures, analytical support to do a study on a UDMH N_2O_4 problem that I was having. They were quite busy up here, I'm sure, and I've talked this over with Colonel Peterson. Believe me, I'm not trying to criticize anybody; I'm just trying to point out a fact that exists right now. I did get an answer, probably about a month later, that they were still working on it and didn't have procedures for UDMH and N_2O_4 . Well, this surprised me considerably, being that I had only been at Edwards a month, and I knew that Edwards AFB had been concerned with this particular project for over a year, and I'm certainly sure that people in AFSC must have known that we were working with N_2O_4 and UDMH and hydrazine and these materials at least as early as I did, which has been some few years back. Today we heard Captain Smith discuss the analytical and sampling problems of the Titan II fuels and oxidizer, and we still don't have these problems solved for N_2O_4 and UDMH, and this is a year later from the original request that I put in.

Now, what's the reason for this? I think we've discussed this fairly well. They say, - well, we've got to generate support requirements for this thing. Well, this is true. However, anybody that's been in this business long enough, and I probably haven't been in it long enough, but I've been in it long enough to know that to start developing analytical procedure in sampling methods for some of the things that we are working with right now, you don't generate over a period of a month or over two months or three months; and I say that these things should have been started many years before I needed a requirement for it at Edwards. We're getting into this area right now, and within twelve to eighteen months we'll be firing large quantities of these motors where our problems are going to be magnified many times. We are getting into larger toxic facilities; we're getting into larger fluorine studies, and somewhere along the line these requirements are going to have to be generated now, and these procedures are going to have to be developed. I don't think the laboratories right now are currently staffed anywhere near the amount of people that they are going to take, for example, on this beryllium study in itself, and this is the reason why I say that it is not the fault of the laboratory. Major Johnson had to use 50% of his chemists for the past four months trying to get the work done for my particular project. He still has all his other work coming in, and I'm sure this is one of the reasons he is possibly 30% behind in his work right now, because I've actually taken up 50% of his time for a quarter of a year. I don't know what the problem is; Mr. Poth says that he's had a valid request in for a year for one person. I say he probably needs twenty people, and Captain Powell probably needs just as many if we are going to be as dynamic an organization as we think we are.

Just as an aside as to the implications, as far as I've been concerned, if we have anything to offer in the Air Force at all, it's the fact that we have Environmental Health Laboratories here that can support us. My personal belief is, as far as Industrial Hygiene Engineering is concerned, one of the biggest things we have to offer, as a selling point for us, is the fact that we have the support of groups such as these Environmental Health Laboratories to help us out with our problems. We talk about the team approach; what's a team approach at most bases? There is only one engineer there to help you. You want chemical support. In any of these things, nobody's an expert within himself, and we need these people, and we have to have these people to get this work done. First of all, there are not too many people either in or out of the Medical Services who know these laboratories exist. When you get to some of these other places and start having to deal with facilities and chemists, they have no idea that these

laboratories exist. So the first thing you have to do is sell them on the fact that these people are here to do us a service and to get the work done through them. So I've been selling this to the people at Edwards for quite some time, because I was quite familiar with both Major Johnson and Captain Powell, and I knew just what their capabilities were, and I have the complete confidence that our ultimate salvation is that we are going to have Environmental Health Laboratories that are going to help us. So I did sell them on it, and this was probably my chance to show these people down there just what these Environmental Health Laboratories could do.

Well, you can imagine the response that I get now when I've also at the same time been trying to sell them on the fact that I've got a project right here that we have been working on for quite some time. They are talking about \$75,000.00 budgets; we are talking about millions of dollars involved in this project just for occupational hazard analyses. Now I go to these people and want to get them, for example, to be the coordinators, the people that are going to help us out on this thing; and all I'm getting is opposition, because the only thing they relate this to, is the actual experience that they've already had with these laboratories. This is a really serious problem, and something is going to have to be done to get more people into these facilities. I think everybody here probably doesn't realize it as much as I do, that some of the data that's being generated in the manner that we get it through some of these contractual efforts. There isn't a contractor in the world that wouldn't take on some of the projects that Captain Powell and these people are doing and doing good work in. It would not matter that yesterday they had never heard about such a project -- they would tell you bold-facedly that "we will do this for you", and they will. And they will come up with a report that probably means nothing. These people are talking about money. Charlie posed the question as to the cost of some of this inhouse work they are doing in research. He knows how much value this is technically. He says he doesn't have any idea what it would cost. We're used to dealing in money at Edwards, and if anybody wants to get down to just what these things cost in contracts, I can give you a fairly good picture of what, for example, Captain Powell's soil percolation studies would cost, and they don't come cheap. You are talking about ten thousand dollar budgets; we are talking about hundred thousand dollars for contractual efforts to get one small study done like Captain Billy Smith reported on here this morning. We are not saving any money by not building this type of capability. They could triple and quadruple their budgets if they are going to supply us with anything. The only thing that we can't buy in this research effort is time, and when we need these things, we need them now. AFSC can't wait for this thing to build up

over one or two years to get one new man assigned. Somebody is just going to have to sit down and say, "We are going to be a dynamic organization and follow along the way the rest of the Air Force is going, or we are going to be dead."

COLONEL DILLS:

I'm going to offer something of a rebuttal regarding the comments which have been made, and I am sure the the others sitting up here in front may have something they want to add, and I hope they do. With regard to some of the propellants, especially the UDMH and the N_2O_4 , the hydrazine going into the Titan II, we in Logistics Command had no knowledge that anything in the form of storable propellants were going to come into the inventory, or were even being considered for any kind of a missile system, until late March 1960. By August of 1960 we had our laboratory people alerted. They were starting to get into the act, and since August of 1960 they have been active in this area. We have realized in Logistics Command that we were not staffed to go ahead and provide all of the services that we have needed. Before I was transferred, we had two or three meetings with our laboratory people discussing this sort of thing to see what was required to go ahead and build up personnel to get the support required and provide the services again which you are asking for. Certainly I think this needs to be done, and I think that as far as the Logistics Command is concerned, one of the best things that all of us can do, and I know that in SAC if I'm not getting the results of analyses back in the time that I think they should be coming back, I'm going to send a wire in to that Headquarters asking why, - not that I'm trying to kick anybody in the seat of the pants, but rather to have them recognize that this is a form of support that I hope they will accept, where they can go talk to their manpower people to try to solicit the things which they have probably been talking to them about before, and which nobody has paid any attention to. Now a part of this has also resulted from the fact that we have just not been communicating with the proper people. There have been too many actions in weapons systems development that medical counterparts have kept themselves completely unacquainted with. I can see really very little reason why we have any problem areas with UDMH at all, especially since this has been in the BOMARC II systems. I don't know when this began. If we had been doing the work that we should have been doing in the years back, we should have UDMH research pretty well off the ground, and certainly all of our problem areas here should be pretty well solved. I don't know how many of you know it, but the Aero-Med Laboratory, after this business came up (and I think this was the first they were advised of the fact that the storable propellants were going to be put into a missile), initiated a contract for some quarter of a million dollars to

go ahead and review all of the various types of instrumentations that were on the market to see which might be made applicable to the sampling of these particular fuels and oxidizers. This work has been completed, but there is a tremendous amount of work that needs to be done. They have been able to progress from a laboratory standpoint to the field testing of this equipment which is still required, and we have felt all along that the analysis of the types of equipment, the field testing of the equipment, should be part of these Environmental Laboratories, rather than going into the other type effort. Dr. Thomas of the Aero-Med Laboratory would have been very happy to have had somebody else pick up this responsibility, but there wasn't anyone at this particular point and time who was qualified. There is a lot of money going into many things, and I think this could well be directed into our own Air Force effort if we can get the proper people together to talk about it.

COLONEL RAMOS:

Well, again I don't want to make any excuses or blame anybody. I fully agree that the line of communication is poor somewhere along the line. I can't understand it; nobody can, I guess, because in every outfit, in every Major Command Headquarters, there are liaison officers. In our Headquarters there is a liaison officer that is a part of every command. As a matter of fact, Navy, Army, Canadian, and I think even the Argentinian Air Force has a liaison there. Furthermore, every report that comes out of our command is of a long distribution list where I am sure that every major command gets one, if not several copies. Where they go, what the distribution within the command is, we have no way of telling. But we know that somewhere along the line there is full communication. Maybe it requires patience; maybe it requires understanding; maybe it requires more effort on the part of those that are interested to look for this. Don't wait for anybody to give it to you, because that may not happen. We of us who are interested have to search for it, and I want to emphasize here the necessity for - well, I hate to use the word "team" as this has been overused during this meeting - the team spirit. It's so easy to criticize other people, but I guess we all do in one way or another. We need a little team action, a little understanding. Let's pull together instead of pulling in different directions.

CAPTAIN KITTELSTAD:

I hope I emphasized that I wasn't trying to make this a matter of personalities or the fact that I was criticizing any environmental health laboratory or anything; believe me, I'm not. The only thing I'm trying to say, the only thing I'm

trying to point out is a problem that exists as far as the support these environmental health laboratories are going to provide us in these projects. Now, I have no question at all about the laboratory support that these people have produced over a period of the past ten years in supporting the normal base functions. Here we are getting into large programs. I know how many people it takes to support these people. We could take their whole laboratory and take them for a week or months at a time, just in support of some of these hazards programs that need to be done. The question is how is this going to be done, whether or not we are going to have to build up an inhouse support. We are certainly going to have to build up some more activity within the environmental laboratories, possibly by getting arms-and-legs contractor-type deals to help them out physically with some of these large programs. Yet, if they are 30% behind now in handling the normal routine procedures, I just can't for the life of me see how they are going to support me even on a consulting basis with some of these problems and programs that we are anticipating now. The only thing I want to say is that I'm not trying to degenerate this into a criticism of anything that is going on. I don't want it on a personality basis. I just say it's a problem that we have in Industrial Hygiene that is going to have to be solved. I think that we are going to have to become more dynamic.

COLONEL PETERSON:

I would like to thank Captain Kittilstad for bringing this to the attention of the audience, as we have been aware of the facts. There are a lot of problems that we are unable to cope with because of shortages. There is no use trying to make excuses for what's gone on in the past, but I would like to make a plea to each and every one of you who have problems, or know that you are going to have problems such as those that Captain Kittilstad discussed this afternoon, if you would bring these to our attention as far in advance as possible, we may be in a position to try to do something about them and get something generated for future work. Now I've been unaware, personally, of some of the things that he discussed today, and apparently they are coming up or have been on the docket for some little time. I would appreciate very much, in order to help us administer this program, that the commands would tell us as far in advance as they possibly can, of work requirements that they are liable to want us to assist them with. How we can do routine things; we're set up to do routine things. It's very, very difficult to get overwhelmed with, say, two or three hundred samples of beryllium analyses all at one time. Again, this is not an excuse, and I'm sure this was not known to Captain Kittilstad more than a few months before it came on,

but if we could know these things in advance, we can try to staff and plan and budget for these, and I'm sure all of you realize that these things don't happen overnight. You don't equip and staff a laboratory and budget for it in a few days. I think this is the best solution to our problem long-range wise. Let us know what you anticipate so that we can make plans to support you. We are eager to support you; we want to support you, but we can't do it on a moment's notice.

COLONEL PIERCE:

I have little to offer, but the first thing I want to say is that just to be completely abjective about this, what Captain Owen Kittilstad said is a plain, ungarbled fact. I haven't been back in the United States very long, but I have had enough connection with the people over in Inglewood, at Ballistics Systems Division, and Systems Command, to know that they don't have time on some of these problems. They know the concurrency concept we have now. There's not any more design phase and testing phase and acceptance phases. All phases happen at the same time, under the concept of concurrency, and what he says is a plain fact, and they will go ahead and let contracts and go ahead with these unless the support's available. I also know how tough it is to get anything out of the manpower people. I know when we set up these command manpower teams to come around and make these management analysis you are talking about, Mr. Poth, to set up work units, and this brings up one more thing. As I recall in the first concept, these laboratories were not intended to do research or to support a research type of operation at all. As I recall, they were supposed to be an operational type of toxicological laboratory, and it was never intended that they support a research effort. But at any rate, let's try to be as objective as we can. AFSC needs help and they need it quick, and they are not going to wait.

CAPTAIN KITILSTAD:

What is the concept now? Are they to support these research efforts or not? I would like to know, because to me there is so much talent concentrated in this area inhouse to the Air Force. Are we going to use it, or are we going to go out on our own and do these types of things? I get the general feeling from talking to the rest of the people here that they not only should be in these programs, they want to be in these areas. After all, they are going to have to gain experience in these areas, particularly in the Missile Systems, with the N_2O_4 and hydrazines that when they get out of the research area² effort they are still going to have these programs to support anyway, so you might as well be in on this research effort at least,

helping us to develop the 613's and the contractual efforts and the technical input that has to go into the contracts. Otherwise, we will have to go out to the contractors in the field to get this done, and rely on the contractors to tell us what we ought to know. I can't do this alone at Edwards, and I don't think there is anyone here in this audience now that could sit down by himself and come out with a contract that would be encompassing and take in every area that is needed to be investigated in this business of propellant research.

CAPTAIN POWELL:

I have a few comments to make about your first statement. There is no doubt that more people both at the Kelly and McClellan Environmental Health Laboratories could be of big assistance to the program. Frankly, the UDMH question that you threw to us was a real curve. It's a complicated sampling and analytical problem. I hope that Captain Smith's paper this morning impressed this upon everyone; and frankly more people would help, but the problem is complicated. It's not one that we could solve in two weeks or a month or six months. It's going to take a long, long time to resolve all the questions about UDMH. I think we are making progress, and a few more people would increase our knowledge in the amount of time we have been involved in it, but I frankly don't think that in this particular problem it would have increased it very much. It would have freed some of our people to work on a full-time basis which would have helped. We do need more people to work on not only UDMH but also on beryllium, and some of the other things with which we are concerned. Some of the other engineers are also asking for information regarding developmental type problems that will be operational in a very short time. But these are complicated problems, and it's going to take time and money, and where you want your answers fast, we've got to have some lead time, too. Frankly, when I looked at your original request, and I know that Colonel Peterson did, too, we both felt that some other people must have been doing this type of work, but we found that the only work had been done by working in percentages and high concentrations. But this is one large but solvable problem, and we do need more people and more support. I'm with you 100%.

COLONEL LEE GRANT:

I'm going to say just a word regarding policy. I tried in my presentation to indicate that certain responsibilities rested with certain commands. When AFSC recently assumed the responsibility for complete development of the Weapons Systems, AFSC was very much interested in, and General Strickland was very much interested in, whether or not he within his own command should develop laboratory capability comparable to that

which exists at McClellan and Kelly laboratories. We felt in our office that to have AFSC develop such a laboratory capability would fractionate the talents that we have within the Air Force, and in a meeting between General Braswell and General Strickland and people from our office, it was decided that AFLC would, through their laboratories, provide the Industrial Hygiene capability to support the research and development program. I feel that the efforts of AFLC, supported by our office, should be directed to enhancing these laboratories so that they can support Captain Kittilstad's operations and operations at other Air Force Bases, etc.

COLONEL BOYSEN:

While I was sitting listening, I was wondering if I ever got stuck with getting up, what I was going to say. I think that there are two things. The first thing is, well, just the answer to this little question, how did this happen? I'm not going to tell you, as this is a trade secret. However, I think it is a trade secret which we're going to use again, and I think if Captain Kittilstad will sit quietly for a little while, I think he is going to see some changes. I can't tell you any more than that, but I think things are getting better. The other thing is, and this has nothing to do with what you have been discussing at all, except that as I listened to Captain Kittilstad, I wondered whether he was volunteering to head up one of these laboratories. This is what they used to do in the old days. When somebody griped about the food, he finally found out that he was a Mess Officer!

AIR QUALITY STANDARDS FOR ATMOSPHERIC POLLUTION

Dr. Bernard Tebbens
University of California

When I see this group in uniform, and obviously thoroughly occupied with their job, I'm no longer surprised that we don't have students any more. They're all already at work; there is nobody left over. I shouldn't say we have no students; I did want to make an additional remark about somebody's statement here a few minutes ago concerning the Base Surgeons that you might contact.

I know from personal experience that quite a few of the Base Surgeons in the Air Force will be well-grounded in occupational health and medicine. I have eight of them under my wing this year. I had four last year, three the year before; at least one of them I saw here a few minutes ago. So in many cases I'm sure you can feel free to consult with the Surgeon with whom you are associated and feel that he does have some knowledge.

The subject I wish to talk about this afternoon has to do with atmospheric pollution. I haven't been completely sidetracked into this field, but have been rather closely associated with it for quite a few years now, and the part of it that I wish to talk about is something that all Industrial Hygiene people know in a slightly different way, the air quality standards.

All of you are certainly familiar with air quality standards as they are applied in a work place. This is nothing new. However, the new part, as far as the outdoor air is concerned, is the very recent establishment of air quality standards which have the same purpose in mind; namely, to be guideposts for good practice in a community at large. Actually, air quality standards aren't as recent as I've just mentioned as being only a couple of years old. There have been some in effect for a period of perhaps ten years in Los Angeles. There a specific problem has occurred in the outdoor atmosphere, and in Los Angeles for some ten years there have been air quality standards for carbon monoxide, nitrogen oxides, sulphur dioxide, and ozone. These are a special kind of air quality standards in that they are emergency standards. When alerts are called in Los Angeles, it is because one or another of these chemicals has reached a concentration which is considered to have significance to the population as a whole.

The alert for carbon monoxide is interestingly enough at 100 parts per million by volume, which is a number you are all acquainted with; for nitrogen oxides 3 parts per million by volume; for sulphur dioxide 3 parts per million by volume; and for ozone 0.5 part per million by volume. The only one of those standards which has been exceeded in

Los Angeles outdoor air is that for ozone; it has been exceeded by several tenths of a part per million on quite a few occasions.

Now in comparing that ozone MAC, so to speak, for outdoor air with that with which we're familiar in work places, it is interestingly enough higher than the presently accepted MAC for the work place environment. This is a true anomaly which I can explain only in terms of the outdoor alert concentration, referring to an emergency kind of situation rather than to day-after-day living with a chemical compound. It has an additional explanation, namely, that the ozone allowable concentration in a work place has been reduced quite drastically in the last three or four years from 1 to 0.1 part per million.

Now, there are really some fundamentally more important air quality standards quite recently promulgated in the State of California. These are the standards of the State Department of Public Health, promulgated in 1959, which have to do with four kinds of material. One is oxidant, any oxidizing characteristic of the atmosphere; the second is sulphur dioxide; the third is carbon monoxide; and fourth is particulate material. The bases for these air quality standards are quite different from the emergency kind of thinking and are certainly different from those with which we have to do in Industrial Hygiene. Let's look at a couple of them; let's look at the base line kind of thinking that's involved.

The State of California decided to set up air quality standards under three different headings. The first is called adverse, air quality standards that relate to some adverse situation; the second, to what is known as a serious situation; and the third, to emergency. Now, the adverse philosophy is that, if a chemical produces a nuisance characteristic of some sort, the concentration above which this nuisance occurs should be the baseline. The serious category has to do with the possibility that a concentration of a chemical will produce a physiologic or possibly pathologic effect on humans, and the third is that humans might be in real trouble, namely, an emergency.

Well, with carbon monoxide, for example, there is no adverse characteristic in the sense of being a nuisance. You don't smell it; you don't see it; you don't feel it, so carbon monoxide doesn't have any adverse limit. It has a limitation, however, in terms of possible serious effect and the limit is as follows: 30 parts per million for an eight hour period would be considered serious, and similarly, 120 parts per million for one hour would be considered serious. The reason is that it is known, and this was carefully studied, that there would be interference with oxygen transport in the human body at these concentration-times. There is, however, no presently established emergency limit for carbon monoxide.

For oxidants and oxidizing characteristics, the limit is under an adverse nomenclature or category, and it is 0.15 parts per million by volume of an oxidant, measured by a specific technique. The reason that is called an adverse limit is that above that concentration one begins to have eye irritation, a nuisance characteristic; one begins to have damage to vegetation, an economic and nuisance characteristic, and so this is an adverse limit; there is no serious or emergency limit set on oxidants.

For total particulates there is an adverse limit, and this has an interesting baseline. It is a nuisance now, or possibly it has an economic effect. The limit for particulates is that there shall be at least a 3-mile visibility throughout the atmosphere, when the relative humidity is less than 70%. This was established from data that had to do with aircraft; when the visibility drops below 3 miles, there is some significant change in landing patterns. So it's at least a nuisance for air transportation and has an economic effect as well. There is no serious or emergency level for this group of entities you can call particulate material.

And finally for sulphur dioxide, the criteria for air quality fall under all three categories; adverse, serious, and emergency. This is because sulphur dioxide has perhaps been studied for a longer period of time than any other individual chemical in the ways that it produces nuisance or injury, or the many effects that are involved. With sulphur dioxide, the adverse air quality standard is 0.3 of a part per million for eight hours, or 1 part per million for one hour, the basis being the possibility of damage to many kinds of vegetation. It has nothing to do with human beings at all, just damage to certain kinds of vegetation for extended exposures to even rather low concentrations of sulphur dioxide. The serious criterion is 5 parts per million for one hour. In Industrial Hygiene we say that 5 parts per million is allowable for eight hours. But we're dealing with an entire population in the outdoor air. The reason for this particular limit is that there is a possibility of bronchial constriction in human beings at this level of exposure. The emergency level is established at 10 parts per million for one hour since it is presumed, and probably certain, that some individuals would feel serious distress and might be very seriously injured.

These are the kinds of standards that now are available as to air quality outdoors. How can they be used as in our own practice of industrial hygiene? In the latter case we take appropriate measurements in our work places and use guidelines to determine either that we have a satisfactory work place from air quality standpoint, or that the quality has to be improved. The outdoor standards have the same real meaning, at least in the State of California, and they of course have no similar meaning anywhere else. This is a State set of standards.

The standards were produced too far after the fact in Los Angeles to do much about it there immediately. I mean they are trying hard to improve their environment, but it is going to take a while. However, in the San Francisco Bay Area, where we have a similar air pollution control district, at least one of these standards had some immediate value, and that was the standard for sulphur dioxide. In the San Francisco Bay Area where air pollution control activities are fairly well under way, a regulation was being discussed at the time that these standards became available. After much argument about sulphur dioxide in the Bay Area, it suddenly occurred to some very bright person - and I can name him, Mr. Dale Hutchison - it suddenly occurred to him, why don't we use these standards? They have the weight of careful thought in the State Health Department; let's make use of them, just as we would say, let's make use of standards in Industrial Hygiene. So, rather than say in the Bay Area you cannot put out sulphur dioxide into the atmosphere, it is rather a part of the regulation there, that sulphur dioxide can be emitted to the atmosphere providing the ground level concentrations do not exceed certain limits.

Now this sounds like it puts a big job on the air pollution control district. It does, in a way, but there is another stipulation in this regulation to the effect that an emitter of sulphur dioxide may emit more than 2,000 parts per million of SO_2 in his stack effluent, providing he takes the responsibility of ground level monitoring to stay within certain limits. If, on the other hand, the emitter chooses to emit less than 2000 parts per million by volume from a stack, it is the responsibility of the control agency to do the ground level monitoring. While this sounds like a strange combination of arrangements, it is an attempt to equalize the responsibility. It might be easier for a given emitter to control the SO_2 below some level and say, "Well, now you're responsible to find out how much this is outdoors." On the other hand, some emitters of sulphur dioxide said, "We know we are going to exceed 2,000 parts per million, but we put our stack up there 600 feet so it wouldn't produce a noxious ground level concentration." To that person it is simply said, "all right; you can continue to prove that you are not exceeding ground level limitations." Now as far as I know, this is working out quite well.

There suddenly crops up another possibility here, and this may throw us all into a tizzy before long. Recent research indicates that sulphur dioxide reacts in the atmosphere with hydrocarbons and nitrogen oxides to produce an aerosol, particulate material. Now this is laboratory research that's not proven for the outdoor situation as yet, but what if it is proven absolutely that sulphur dioxide in low concentrations does react in the atmosphere to produce an aerosol? We find ourselves faced with a set of chemicals in the air that produces an excess of particulate material in terms of another standard,

and we may have to do some revising. This, however, as far as our Bay District is concerned, really awaits a change in standards by the State Health Department, because we're still saying basically, "We believe you were right in setting the standards as you did." A few slides will further illustrate the air quality standards and their use.

SLIDE 1.

<u>Adverse Level</u>	<u>Serious Level</u>	<u>Emergency Level</u>
1 ppm for 1 hour or 0.33 ppm for 8 hours (plant damage)	5 ppm for 1 hour (bronchoconstriction in human subjects	10 ppm for 1 hour (severe distress in human subjects

Slide 1 shows the State standards for sulphur dioxide, the adverse level, the serious level, and the emergency level, with the indication as to why the standard exists. Adversely, 1 part per million for one hour or 0.3 parts per million for eight hours can produce damage to vegetation, and we don't want this in the Bay Area. At the serious level, 5 parts per million for one hour can cause bronchial constriction in human subjects; we don't want this to happen either. The emergency level is set at 10 parts per million for one hour because of possible severe stress in human beings, especially those who are already partly incapacitated.

SLIDE 2.

MAXIMUM ALLOWABLE SULFUR DIOXIDE GROUND-LEVEL LIMITS

Avg. Conc.(c) in ppm (vol.)	Total Cumulative Daily Exposure <u>Duration (t) in Hours</u>		Total Cumulative Monthly Exposure <u>Duration (t) in Hours</u>	
	Between Sunrise and Sunset	Between Sunrise and next Succeeding Sunrise	During Hours Between Sunrise and Sunset	Any Time During Month
Column 1	Column 2	Column 3	Column 4	Column 5
1.51 or over	0.05	0.10	1.00	2.00
1.5	0.62	1.24	4.40	8.80
1.4	0.67	1.34	5.10	10.20
1.3	0.73	1.46	5.90	11.80
1.2	0.80	1.60	6.90	13.80
1.1	0.89	1.78	8.30	16.60
1.0	1.00	2.00	10.0	20.00
0.9	1.14	2.28	12.4	24.80
0.8	1.33	2.66	15.6	31.20
0.7	1.60	3.20	20.4	40.80
0.6	2.00	4.00	27.8	55.60
0.5	2.67	5.34	40.0	80.00
0.4	4.00	8.00	62.5	125.00
0.3	8.00	16.00	111.0	222.00
0.2 or less	No limit	No limit	No limit	No limit

Slide 2 is a table from the regulation in the Bay Area on sulphur. It is the basic ground level restrictions for sulphur dioxide. It specifies certain concentrations up to 1.5 parts per million by volume and an allowable time in any twenty-four hour period during which that concentration can be allowed. I call to your attention that this is outside the boundaries of the property of the emitter; there is no attempt in the regulation to control sulphur dioxide within the gates of a given chemical plant, nor by the regulation is there an attempt to control sulphur dioxide exposure inside of the plant. That is specifically excluded.

STATE STANDARDS

1. Adverse level
 - 0.3 ppm for 8 hours
 - 1.0 ppm for 1 hour
2. Serious level
 - 5.0 ppm for 1 hour
3. Emergency level
 - 10.0 ppm for 1 hour

BAAPCD LIMITS

- 0.3 ppm for 8 hours
- 1.0 ppm for 1 hour
- 1.5 ppm for 0.05 hour
- 1.5 ppm for 0.05 hour

Slide 3 shows the way in which the State standards were used; State standards are shown on your left and the Bay Area Air Pollution Control District standards for ground level concentration, on the right. Under adverse, the State says, as we pointed out, 0.3 of a part per million for eight hours, 1 part per million for one hour. Our standard in the Bay Area says exactly the same thing. For the serious level, however, where the State says 5 parts per million for one hour might cause bronchial constriction, in the Bay Area the regulation says no more than 1.5 parts per million for 0.05 of an hour, i.e., three minutes. In other words, we are going to be pretty careful on that subject, and similarly, at the emergency level, we hope we never reach it, because we restrict ground level concentrations far below that possibility.

I trust that I have clarified that there are bases for outdoor air quality standards, different from those in a working environment, and that they can be applied in an outdoor environment.

EVALUATION OF TWO NEW PORTABLE TOXIC VAPOR DETECTOR KITS

Mr. Herbert S. Dankman, Lt. Paul Beecher
Lt. Col. Francis S. Smith, Lt. James O. Pierce II

Speaker:

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The development of industrial hygiene instrumentation is proceeding at a rapid rate, the trend being toward versatility and miniaturization. An interesting approach in this respect has been the development of glass reagent-filled indicator tubes which are sensitive to a wide variety of chemicals. Because of their possible wide-spread application throughout the Air Force Sanitary and Industrial Hygiene Engineering program, two representative kits were tested to obtain some idea as to their accuracy and operating characteristics.

Each kit consisted of a 100 cc pump and a variety of glass tubes filled with reagent-impregnated silica gel. As air is drawn through the tubes, the contaminant to be measured reacts with the reagent, producing a colored stain. Either the stain length or comparison of the stain colors with a standard, is used to measure the contaminant under consideration. Kit No. 1 employs a bellows type pump, whereas Kit No. 2 employs a syringe type pump. Both kits have controlled flow rates.

Since a thorough study of both kits and each of their tubes could take as long as from one to two years (for example, to test the shelf life of tubes and compare batches), it was decided to conduct a limited screening type of test of some of the more common tubes. These tests were conducted at ambient room temperature and relative humidity, using a 1000-liter calibration chamber.

Details of procedures used in the tests, and results obtained, are listed on the following pages. Results, generally, were not impressive, and it was concluded that the kits were not sufficiently well developed to warrant their adoption by the U.S. Air Force. It was particularly felt that the kits might be dangerous tools in the hands of inexperienced personnel. Additional testing would be warranted if these kits are further developed.

4. Test Results:

a. 0.1 Trichlorethylene Detector Tube:

(1) General Information:

- (a) Date of Test: 4/26/60
- (b) Batch No. 9230 (Special)
- (c) Expiration date of tubes: September 1961
- (d) Number of strokes of pump per sample: 5
- (e) Mls. of air sampled per stroke: 100

(2) Results:

(a) 0.00 mg/l @ 23°C:

Tube No. 1, 2, 3: No discoloration of tubes was noted after five strokes.

(b) 0.25 mg/l @ 21.6°C:

Tube No. 4: The resulting stain was concentric up to 1/2 the distance between the 0.00 and the 0.25 mg/l line. The maximum length of the stain was approximately 1/3 the distance between the 0.25 and the 0.50 mg/l line. The stain was slanted, and non-symmetrical. Estimated error equals 50%.

Tube No. 5: The resulting stain was concentric, and covered approximately 2/3 of the distance between the 0.00 and the 0.25 mg/l line. Estimated error = 33%.

Tube No. 6: The stain was concentric and covered approximately 1/3 of the distance between the 0.00 and 0.25 mg/l line. Estimated error = 66%.

(c) 0.5 mg/l @ 23.5°C:

Tube No. 7: The resulting stain was concentric up to $1/4$ of the distance between 0.00 and 0.25 mg/l line. The maximum length of stain was slightly past the 0.25 mg/l line. Estimated error = 88%.

Tube No. 8: The resulting stain was concentric up to $1/2$ the distance between 0.00 and 0.25 mg/l line. The maximum length of stain was slightly past the 0.25 mg/l line. Estimated error = 75%.

Tube No. 9: The stain was concentric, with a maximum length of approximately $1/3$ of the distance between the 0.25 and 0.50 mg/l line. Estimated error = 34%.

(d) 1.0 mg/l @ 24.2°C:

Tube No. 10: The resulting stain was concentric with a maximum stain length of approximately $1/3$ the distance between 0.25 and 0.50 mg/l line. Estimated error = 66%.

Tube No. 11: The stain was concentric with a maximum stain slightly past the 0.50 mg/l line. Estimated error = 50%.

Tube No. 12: The stain was concentric, with the maximum stain length $1/3$ of the distance between 0.50 and the 1.00 mg/l line. Estimated error = 33%.

Tube No. 13: This sample was taken with a different hand pump than the one used on the previous samples, and the resultant stain was concentric and slightly over the 0.50 mg/l line. Estimated error = 50%.

(e) 1.5 mg/l @ 24°C:

Tube No. 14: The resulting stain was concentric up to the 0.50 mg/l line. The total stain length was $\frac{3}{4}$ of the distance between the 0.50 and 1.00 mg/l line. Estimated error = 66%.

Tube No. 15: The stain was concentric up to the 0.50 mg/l line. The total stain length was 1.00 mg/l. Estimated error = 66%.

Tube No. 16: The resulting stain was concentric, having a total stain length slightly higher than 0.50 mg/l. Estimated error = 66%.

(f) 2.0 mg/l @ 23°C:

Tube No. 17: The resulting stain was concentric up to $\frac{3}{4}$ of the distance between the 0.50 and the 1.00 mg/l line. The total stain length was 1.00 mg/l. Estimated error = 62%.

Tube No. 18: The resulting stain was concentric up to the 0.50 mg/l line. The total stain length was $\frac{1}{2}$ the distance between the 0.50 and the 1.00 mg/l line. Estimated error = 75%.

Tube No. 19: The resulting stain was concentric up to $\frac{1}{2}$ the distance between the 0.50 and 1.00 mg/l line. The total stain length was slightly past the 1.00 mg/l line. Estimated error = 62%.

(3) Upon completion of the test results, the 19 tubes were subjected to a strong light for approximately one hour for the purpose of photographing the results. After photography, the tubes were placed in a closed box and when observed the next day, approximately 15 hours since completion of the test, the stains were now all concentric and there was a sharp line of demarcation between the stained and unstained portions of silica gel. The following table will show a comparison of the two readings, one taken at the time of the test and the other the next day. The value given for the first reading in the left-hand set of data is the maximum point on the tube where the stain still was concentric;

that is, the highest concentric reading obtained. The value given for the first reading in the right-hand set of data is the reading corresponding to the maximum stain length where staining was not concentric. Since we do not have a linear scale between each concentration line on the tube, the readings listed are at best an estimate of the concentration.

<u>Exposed to conc. of 0.25 mg/l Tube No.</u>	<u>1st Read- ing at highest concentric point</u>	<u>New Read- ing</u>	<u>Dif- fer- ence</u>	<u>1st Read- ing at point of maximum Stain</u>	<u>New Read- ing</u>	<u>Dif- fer- ence</u>
4	0.15	0.20	+0.05	0.35	0.20	-0.15
5	0.20	0.05	-0.15			
6	0.10	0.10	none			

Exposed
to conc.
of 0.50
mg/l
Tube No.

7	0.10	0.20	+0.10	0.30	0.20	-0.10
8	0.15	0.20	+0.05	0.30	0.20	-0.10
9	0.35	0.35	none			

Exposed
to conc.
of 1.0
mg/l
Tube No.

10	0.35	0.30	-0.05			
11	0.50	0.60	+0.10			
12	0.70	0.70	none			
13	0.50	0.40	-0.10			

Exposed
to conc.
of 1.5
mg/l
Tube No.

14	0.50	0.95	-0.45	0.90	0.95	+0.05
15	0.50	1.00	+0.50	1.00	1.00	none
16	0.55	0.55	none			

Exposed
to conc.
of 2.0
mg/l
Tube No.

17	0.85	1.20	+0.35	1.0	1.20	+0.20
18	0.50	0.85	+0.35	0.75	0.85	+0.10
19	0.75	1.05	+0.30	1.05	1.05	none

The tubes were then allowed to remain uncovered in the laboratory for a period of one week and no change in stain length was observed over that observed the morning after the test. There was a slight fading of color noted.

(4) Conclusions:

(a) The Trichlorethylene tubes tested were not satisfactory for their intended purpose.

(b) The resulting stain lengths were not concentric in many instances presenting a questionable point at which to read the concentrations.

(c) In all cases the tubes read low with the errors ranging from 33% to 88% of the true concentration.

(d) By allowing the tubes to sit overnight, after exposure to strong light, the stains all became concentric and there was some improvement in the values obtained but the errors were still excessive.

b. Toluene Detector Tube 0.25: (Test #1)

(1) General information

(a) Date of test: 12 May 1960

(b) Batch no.: 9022

(c) Expiration date of tubes: January 1961

(d) Description of detector tube:

1. The toluene detector tube is approximately 150 mm. long and has an inside diameter of approximately 5 mm. Viewed in the direction of air flow it has a white precleansing layer, a white reaction layer and a reddish-brown reference layer.

2. The range of the tube for toluene is from 0.25 to 10 mg/l. 0.74 mg/l is equal to 200 ppm of toluene.

(e) Number of strokes of pump per sample: Pump is stroked until color of the reaction layer matches color of the reference layer. The number of strokes will vary, depending upon the concentration. The following table lists the number of strokes required to obtain a color match at various concentrations:

<u>Number of strokes</u>	<u>mg Toluene (Xylene) per liter air</u>
3 - 4	10
5	5
6	4
7	3
8	2
9	1.5
10	1.2
11	1
12	0.75
14	0.5
18	0.25

(r) Mls. of air sampler per stroke: 100

(2) Results:

(a) 0.25 mg/l @ 24° C:

Tube No. 1: Color of reaction layer matched color of reference layer after 18 strokes. The color of the reaction layer and that of the reference layer were almost identical upon completion of the test. Upon observation, 15 to 20 minutes later several observers agreed that the color of the reaction layer was then slightly darker than that of the reference layer.

Tube No. 2: Color of the reaction layer was slightly darker than the color of reference layer after 17 strokes. After 18 strokes, the color was considerably darker.

Tube No. 3: Color of the reaction layer was approximately that of the reference layer after 18 strokes.

(b) 0.75 mg/l @ 26°C:

Tube No. 4: Color of the reaction layer was darker than the color of the reference layer after 11 strokes. Reaction layer darkened rapidly with time and within 5 minutes after the initial observation was considerably darker than the reference layer. Reaction layer had a reddish-purple hue, whereas the reference layer has a reddish-brown hue.

Tube No. 5: Color of the reaction layer was similar to that of the reference layer after 12 strokes; however, it darkened rapidly and was considerably darker after about 5 minutes. Reaction layer had a reddish-purple hue, whereas the reference layer has a reddish-brown hue.

Tube No. 6: Color of the reaction layer was darker than color of the reference layer after 12 strokes, and continued to darken rapidly. Reaction layer had a reddish-purple hue, whereas the reference layer had a reddish-brown hue.

Tube No. 7: Color of the reaction layer was similar to that of the reference layer after 10 strokes; however, within 5 minutes the color of the reaction layer was darker.

(3) Comments:

(a) Testing was discontinued after a concentration of 0.75 mg/l because of poor results obtained.

(b) The color of the reaction layer was not the same as that of the reference layer, making it almost impossible to know when to stop stroking the pump. This was more noticeable at a concentration of 0.75 mg/l than at 0.25 mg/l. The reaction layer had a reddish-purple hue, whereas the reference layer has a reddish-brown hue.

(c) The grain size of the silica gel in the reaction layer is smaller than that of the reference layer which made visual comparison more difficult. Finely ground white particles were also dispersed throughout the reaction layer which further interfered with color comparison.

(d) Color in the reaction layer changed rapidly over a short time interval which made it extremely difficult to know when to stop stroking the pump. Five observers were used throughout this test and as the tube was passed from one to another for comment. The color kept getting darker and no agreement could be reached. After one-half to one hour, all tubes, even when kept in the dark, developed a dark reddish-purple color.

(e) As testing progressed from one tube to another at a given concentration, the initial concentration of vapor in the tank was reduced in relation to the amount of vapor laden air withdrawn from the tank. After tube nos. 4 to 7 were tested, a total of 4500 cc of vapor-laden air had been withdrawn and replaced by room air. This resulted in a calculated reduction in vapor concentration of only 0.42% which would not significantly alter the results obtained.

(4) Conclusions:

(a) The toluene detector tubes tested were not satisfactory for their intended purpose.

(b) Too many errors were encountered in trying to match the colors of the reaction layer to that of the reference layer to permit even an estimate of the accuracy of these tubes.

(c) It is our opinion that considerable improvement is necessary in the toluene detector tube before its use could be at all warranted for industrial hygiene purposes.

c. Toluene Detector Tube 0.25: (Test #2)

(1) General information:

(a) Date of test: 29 June 1960

(b) Batch No.: 0060

(c) Expiration date of tubes: April 1962

(d) Number of strokes of pump per sample: 10

(e) Mls. of air sampled per stroke of pump: 100

(2) Description of Detector Tube:

(a) The detector tube is approximately 150 mm. long and has an inside diameter of approximately 5 mm. It has eight annular markings corresponding to various concentrations.

(b) Range of the tube for toluene is from 0.1 to 7 mg/l.

(c) In use, the pump is stroked 10 times and the concentration determined from the length of stain developed.

(3) Results:

(a) Three tubes were tested at each of the following concentrations: 0.25, 0.75, 1.00, 1.50 and 2.00 mg/l. Data obtained are listed in Table No. 1.

(b) It can be seen from the data contained in Table No. 1 that the results reported by both observers were almost identical with only a few differing by more than 10%.

(c) During this test, the measured concentrations corresponding to the maximum concentric stain length, the maximum stain length and the average of these two values were recorded in order to determine which value would most closely correspond to the test concentration.

(d) Values based on the maximum concentric stain length (column 13, Table No. 1) had the lowest average percent of error from the true concentration (+11.8%; however, the average value is misleading since inspection reveals that individual results were in error from a high of +60% to a low of -80%.

(e) Values based on the maximum stain length indicated an average error of +93.3% with individual errors being even greater.

(4) Comments:

(a) This tube differs from the toluene detector tube used in Test No. 1 in that it operates upon the stain length principle rather than color comparison as was used in the original tube.

(b) Toluene detector tubes, Kit #2, were simultaneously tested along with Kit #1 toluene tubes.

(c) Prior to the last tube being tested at each concentration, a total of 2300 cc of vapor-laden air had been withdrawn from the tank and replaced by room air. This resulted in a calculated reduction in vapor concentration of only 0.21% which would not significantly alter the results obtained.

(5) Conclusions:

(a) The new toluene detector tubes were a slight improvement over the old tubes; however, they are still not satisfactory for their intended purpose.

d. Alcohol Detector Tube 0.2:

(1) General information:

(a) Date of test: 28 July 1960

(b) Batch No.: 8305

(c) Expiration date of tubes: December 1960

(d) Description of tubes:

1. The overall length of the tubes is approximately 150 mm., whereas the inside diameter is approximately 5 mm. The alcohol concentration is determined by the length of stain developed in the tube and there are six annular markings on the tubes which correspond to certain alcohol concentrations. The markings are non-linear.

2. The range of the tubes for methanol is from 0.2 mg/l to 40 mg/l and for ethanol from 1 mg/l to 40 mg/l. Two hundred (200) ppm of methanol corresponds to 0.26 mg/l.

3. The number of strokes of the pump during a test depends upon the ambient temperature. For concentrations greater than 1.0 mg/l, the pump was stroked 5 times during this test (conducted at 25°C) and the concentration was determined from the length of stain developed. For concentrations less than 1.0 mg/l, the pump is stroked until the discoloration reaches the first marking on the tube (1.0 mg/l). The concentration is then computed from the following formula:

$$\text{Mgs. of methanol/liter of air} = \frac{\text{Tube Factor}}{N}$$

N = number of strokes

Tube factor = temperature dependent factor given in the instructions. Was 5 at 25°C.

(e) Mls. of air sampled per stroke: 100

(2) Comments:

(a) During the test, observers could not readily discern when the 1.0 ml/l mark was reached due to the streaky and uneven discoloration of the tube. In many cases one streak of color would have already reached the 5.0 mg/l mark before the stain became concentric at the 1.0 mg/l mark.

(b) During this test, methanol detector tubes from Kit. No. 2 were simultaneously tested along with the tubes from Kit No. 1, adding to the reduction of the initial concentration of vapor in the tank. Prior to the last tube being tested at the lowest concentration (the concentration which required the greatest number of strokes on the Bellows pump), a total of 2900 cc's of vapor-laden air had been withdrawn and replaced by room air. This resulted in a calculated reduction in vapor concentration of only 0.27% which would not significantly alter the results obtained.

(3) Results:

(a) Tubes were tested at concentrations of 0.073, 0.146, 0.217, 0.290, 0.3625, 0.435, 1.305 and 4.35 mg/l. Data obtained are listed in Table 2. All of the data contained in this table are based upon the maximum point of total concentricity.

(b) It can be seen from the data in Table 2 that the results deviate considerably from the true concentration. The error ranged from a low of 91.6% to a high of 589.7%. The average error was 242.9%. It can be noted that in all cases, results obtained were higher than the test concentration.

(4) Conclusions:

(a) The Kit No. 1 alcohol detector tube did not give satisfactory results when tested against methanol.

(b) Staining of the tubes was streaky and not concentric and it was impossible to determine where the stain was at any given time.

e. Trichlorethylene Detector Tube

(1) General information:

(a) Date of test: 26 April 1960; 13 May 1960

(b) Expiration date of tubes:

1. Tubes nos. 1-10: 17 September 19602. Tubes nos. 11-15: 30 October 1960

(c) Description and method of use of detector tube:

1. The detector tube is a glass tube approximately 4" in length and 1/8" inside diameter. The reagent is absorbed on fine grain silica gel which is packed into the tube and retained in place by cotton pledgets at either end of the tube. The length of the silica gel reaction layer varies slightly from tube to tube.

2. A second glass tube approximately 3" long and 1/8" inside diameter containing an oxidizer tube is joined to the detector tube with a small piece of rubber tubing and air is drawn first through the oxidizer tube and then through the reaction layer.

3. If air containing trichlorethylene is drawn through the detector tube, a reddish-brown color develops with total length of stain proportional to the trichlorethylene concentration. A calibration chart is provided with each box of tubes in order that the atmospheric concentration associated with each stain length may be determined. Concentrations up to 400 ppm may be measured.

4. One pump stroke or 100 cc of air are sampled per test.

(d) Testing for interferences was not accomplished. The manufacturer states that tetrachlorethylene, dichlorethylene, vinylchloride, chlorobenzene, hydrogen chloride, bromide, chlorine, iodine, nitrogen dioxide and ozone may interfere.

(2) Test Results:

(a) Three tubes were tested at each of five concentrations, 0.25, 0.50, 1.0, 1.5 and 2.0 mg per liter of air and data obtained are listed in Table No. 3. Testing was carried out simultaneously with the testing of the trichlorethylene tubes from Kit. No. 1.

(b) Two observers were used throughout the testing and, after each tube was used, the observers independently determined the concentration from the calibration chart. The length of the reaction layer and the length of the stained portion of the reaction layer were then measured with a ruler and the concentration was determined from the calibration chart using these measurements. Concentrations determined by the observers by placing the tube on the calibration chart were within 10% of each other or closer. Measurements of the stain length by each observer and the concentrations obtained from the chart using these measurements were almost identical. The average results obtained by placing the tubes on the calibration chart and those obtained by measurement were within 10% of each other or closer. The results reported in Table No. 3 are the average results of the two observers as determined by stain length measurement.

(c) It can be seen from the data in Table No. 3 that the results of individual tests were generally within $\pm 10\%$ of the test concentration and that the highest deviation from the test concentration was -15%. Three results, tubes No. 4, 5 and 7 were considerably in error; however, this was determined to be due to a leak around the rubber seal in the pump into which the detector tube is inserted. A different pump was, therefore, used for test No. 6 and the original pump was again used for test No. 7. After test No. 7, the rubber tube holder was replaced and no further difficulty was noted.

(3) Conclusions:

(a) Concentrations as determined with the detector tube were very good and generally within $\pm 10\%$ of the test concentration with occasional tests showing a greater deviation. The largest deviation was -15%.

(b) Some difficulty was encountered with leakage around the rubber tube holder in the top of the pump. The tube holder is held in position against the pump orifice by a threaded metal sleeve. If the sleeve is tightened excessively it has a tendency to shear off the rubber flange at the bottom of the tube holder and/or to force the flange out from under the sleeve. This can be done by the pump user without his being aware of this and can, therefore, yield low results due to leakage around the tube holder. It is therefore advisable to periodically check the volume of air drawn to insure against leakage due to this or other malfunctions. When functioning properly, air volumes were estimated to be quite close to 100 cc.

f. Toluene Detector Tube: (Test No. 1)

(1) General information:

- (a) Date of Test: 12 May 1960
- (b) Expiration date of tubes: 2 March 1960
- (c) Description and method of use of detector tube:

1. The detector tube is a glass tube approximately 5" long and 1/8" inside diameter. The reagent is adsorbed on fine grain silica gel which is packed into the tube and retained in place by what appears to be cloth pledgets at either end of the tube. A portion of the silica gel approximately 5 mm in length is stained reddish-orange at the end of the tube which is inserted into the pump.

2. If air containing toluene is drawn through the detector tube, a reddish-brown color develops, with total length of stain proportioned to the toluene concentration. A calibration chart is provided with each box of tubes in order that the atmospheric concentration associated with each stain length may be determined. The calibration chart is based on an air temperature of 68°F (20°C). Readings are increased by 5% per each 10°F less than 68°F, for temperature between 68°F and 50°F, and are reduced by 5% per each 10°F above 68°F for temperature between 68°F and 90°F. Range of the tubes is from 10 - 1500 ppm.

3. One pump stroke or 100 cc of air are required per sample.

(d) Other cyclic hydrocarbons and ethers produce similar discolorations and may interfere.

(2) Test Results:

(a) Three tubes were tested at each of five concentrations (0.25, 0.75, 1.0, 1.5 and 2.0 mg/l of air) and data obtained are listed in Table No. 4. Testing was carried out simultaneously with the testing of the toluene detector tubes from Kit No. 1.

(b) Two observers were used throughout the testing and after each tube was used the observers independently determined the concentration from the calibration chart. The length of the reaction layer (the original unstained silica gel portion) and the length of the stained portion of the reaction layer were then measured with a ruler and the concentration was determined from the calibration chart using these measurements. The results obtained by placing the tubes on the calibration chart and

observing the reading and those obtained by measurement were almost identical. Therefore, only the results obtained by observation are reported in Table No. 4.

(c) It can be seen from the data in Table No. 4 that the results reported by the two observers for each test are quite close to each other in almost all instances, with only occasional deviations as high as 15% from each other. The average temperature corrected results of the two observers deviated from the true test concentrations by a low of 5.8% to a high of 27.5%. The average percent of error for all of the tubes was -11.3%.

(3) Comments and Conclusions:

(a) Results obtained with the toluene detector tube were fair. Although the average error of all the tests was good (-11.3%), individual errors deviated from the true concentration by as much as 27.5%. Since the tubes tested had passed their expiration date, it is possible that improved results may have been obtained with newer tubes.

(b) The measured concentration becomes progressively more difficult to read at higher concentrations, since a small distance on the calibration curve represents a large change in concentration. Possibly more divisions on the chart at higher concentrations would tend to improve accuracy of readings.

g. Toluene Detector Tube: (Test No. 2)

(1) General Information:

(a) Date of test: 29 June 1960

(b) Expiration date of tubes: 1 August 1960

(c) Batch No.: 0118050

(d) Catalog Number: 124

(e) Description and method of use of detector tube:

1. The description and method of use of the detector tube can be found in paragraph e(1)(c) of this report.

(2) Test Results:

(a) Three tubes were tested at each of the following concentrations: 0.25, 0.75 and 1.00 mg/l of air. Due to the availability of a limited number of tubes, only two tubes were tested at concentrations of 1.50 and 2.0 mg/l of air.

(b) Testing was carried out simultaneously with the testing of a new type of Kit No. 1 toluene detector tube.

(c) The same procedure of observation and measurement was used as in the previous test (see par. f(2)(b) of this report).

(d) It can be seen from the data in Table No. 5 that the result reported by both observers were almost identical with only a few observations differing and by less than 10%. The temperature corrected results (column 13) deviated from the test concentration by a low of -1.3% to a high of -51.1%. The average percentage of error of all the tests was -26.4%.

(3) Comments:

(a) It can be noted that all of the results of this test were lower than the test concentration. In the previous test performed on a different batch of tubes (par. e) some of the results were higher and some were lower than the test concentration.

(b) As testing progressed from one tube to another at a given concentration, the initial concentration of vapor in the tank was reduced in relation to the amount of vapor-laden air withdrawn from the tank. After the last tube was tested, a total of 3300 cc of vapor-laden air was withdrawn and replaced by room air. This resulted in a calculated reduction in vapor concentration which would not significantly alter the results obtained.

(c) Immediately upon testing, the color of the reaction layer was a light brown. Approximately 3 to 5 minutes later, the stain changed to a very dark brownish-violet color; however, the length of the stain did not change.

(4) Conclusions:

(a) The results obtained in this second test of the detector tube were poor.

(b) The average error for all of the tubes was -26.4% and the errors ranged from a low of -1.3% to a high of -51.1%.

h. Methanol Detector Tube Test

(1) General Information

(a) Date of Test: 28 July 60

(b) Expiration Date of Tubes: 29 July 62

(c) Catalog Number: 119 (0.02 - 8.0%)

(d) Description and Method of use of Detector Tube:

1. The detector tube is a glass tube approximately 5" long and 1/8" inside diameter. The reagent is adsorbed on fine grain silica gel which is packed into the tube and retained in place by what appears to be cloth pledgets at either end of the tube. The length of the silica gel reaction layer varies slightly from tube to tube. The silica gel is stained orange in color, and upon reaction with methanol the resultant stain is yellowish-green, which turns to a dark green in 5 to 10 minutes.

2. The calibration chart provided with each box of tubes is based on an air temperature of 68°F (20°C). Readings are increased by 1.5% for each °F less than 68°F for temperatures between 68°F and 50°F, and are reduced by 1.5% for each °F above 68°F for temperatures between 68°F and 90°F.

3. Range of the tubes is from 0.02 - 8.0% of methanol by volume.

(2) Test Results:

(a) Two tubes were tested at each of the following concentrations: 0.073, 0.146, 0.2175, 0.290, 0.3625, 0.435, 1.305, and 4.350 mg/liter of air. Data obtained are listed in Table No. 6.

(b) Testing was carried out simultaneously with the testing of methanol detector tubes from Kit No. 1.

(c) It can be seen from the data in Table No. 6 that the temperature corrected results (Column 5) deviated from the true concentrations by a low of -1.3% to a high of +260.3%. The average percent of error of all the tests was 26.2%.

(3) Comments:

(a) The calibration chart provided for the reading of the tubes was of such a nature that 1/16" meant a difference of 200 ppm. Observers had a very difficult time determining the exact length of the stain. One could only ascertain whether the stain length was above 200 ppm or below 200 ppm. For this reason the figures obtained are at best only estimates of the stain length, and the percentage of error column cannot be considered completely accurate.

(b) It can be noted that the results of the test were high for concentration at 0.073 and 0.146 mg/l but were very good for concentrations near the MAC (0.26 mg/l or 200 ppm.) Furthermore, it can be seen that all results for concentrations below the MAC were on the high side, while all results for concentrations above the MAC were slightly low.

(c) Although the average percent of error for all tubes is only 26.2%, this figure is deceiving in view of the fact that of the 16 readings taken, 7 showed a positive percent of error while 9 showed a negative percent of error. Furthermore, the first two readings taken had an average percent of error of 260.3%.

(d) The reduction in vapor concentration in the calibration tank as samples were withdrawn was taken into consideration and was deemed to be insignificant.

(4) Conclusions:

(a) The methanol detector tubes were not satisfactory for their intended purpose and errors ranged from -1.3% to 260%.

Date of Test: 30 June 1960

Tested by: Beecher & Dankman

KIT #1 TOLUENE

Observed: Beecher & Thorpe

(1) TUBE NUMBER	(2) TEST CONCENTRATION IN mgs/liter; and tempera- ture at time of Test	(3) Observed Concentration based upon:	(4) OBSERVER #1 Concentration in mg/L based upon:	(5) Average (3)+(4)/2	(6) Observed Concentration based upon:	(7) OBSERVER #2 Concentration in mg/L based upon:	(8) Average (6)+(7)/2
		Max. Con- centric stain length (cm)	Max. Stain Length (cm)		Max. Con- centric stain length (cm)	Max. Stain Length (cm)	
1	0.25 mg/L @ 21.1°C	0.4	0.75	0.58	0.4	0.65	0.52
2	" "	0.35	0.50	0.43	0.25	0.50	0.37
3	" "	0.00	0.75	0.38	0.10	0.60	0.35
AVERAGE	" "	0.25	0.67	0.46	0.25	0.58	0.41
4	0.75 mg/L @ 21.1°C	1.0	1.4	1.2	1.0	1.4	1.2
5	" "	0.9	1.2	1.15	1.0	1.25	1.12
6	" "	0.6	1.0	0.8	0.75	1.0	0.87
AVERAGE	" "	0.8	1.2	1.05	0.92	1.22	1.08
7	1.00 mg/L @ 24.0°C	1.1	2.0	1.55	1.1	2.5	1.8
8	" "	0.95	1.5	1.23	0.8	2.2	1.5
9	" "	1.2	2.5	1.85	1.2	2.9	2.05
AVERAGE	" "	1.08	2.0	1.54	1.03	2.5	1.76
10	1.50 mg/L @ 25.0°C	1.5	2.2	1.85	1.4	2.0	1.7
11	" "	1.2	2.0	1.60	1.3	2.0	1.65
12	" "	2.0	2.0	2.40	2.0	2.8	2.4
AVERAGE	" "	1.57	2.33	1.95	1.57	2.27	1.92
13	2.00 mg/L @ 25.0°C	2.4	3.3	2.85	2.4	3.3	2.85
14	" "	2.6	3.7	3.15	2.7	3.7	3.2
15	" "	2.8	3.5	3.15	2.8	3.5	3.15
AVERAGE	" "	2.6	3.5	3.05	2.6	3.5	3.05
NOTES:							
1. Column (3): The readings in this column represent the maximum point of point all stains were no longer concentric but were slanted							
2. Column (4): The readings in the column represent the maximum point of the slanted and irregular part of the stains not included in column (3)							
3. Column (5): The readings in this column represent the average of the readings in columns (3) and (4)							

1

KIT #1 TOLUENE TUBE TEST # 2

Expiration Date of Tubes: April 1962
Batch No. of Tubes: 0060

TABLE 1

(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)		
Observed Concentration based upon:	OBSERVER # 2 Concentration in Mg/L		Concentration in mg/L based upon average of both observers				PERCENT OF ERROR BASED UPON:		
Max. Concentric stain length(cm)	Max. Stain Length (cm)	Average ((6)+(7)/2)	Max. Concentric stain length(cm)	Max. Stain Length (cm)	Average Stain Length(cm)	True Concentration (2)	Maximum Concentric Stain Length (9)-(12) 12	Maximum Total Stain Length (10)-(12) 12	Average Stain Length (11)-(12) (12)
0.4	0.65	0.53	0.4	0.7	0.55	0.25	+60.0	+180.0	+120.0
0.25	0.50	0.38	0.3	0.5	0.40	0.25	+20.0	+100.0	+ 60.0
0.10	0.60	0.35	0.05	0.68	0.36	0.25	-80.0	+172.0	+ 46.0
0.25	0.58	0.42	0.25	0.63	0.44	0.25	0.0	+152.0	+ 76.0
1.0	1.4	1.2	1.0	1.4	1.2	0.75	+33.3	+ 86.7	+ 60.0
1.0	1.25	1.13	0.95	1.22	1.14	0.75	+26.7	+ 60.0	+ 52.0
0.75	1.0	0.88	0.67	1.0	0.84	0.75	-10.7	+ 33.3	+ 12.0
0.92	1.22	1.07	0.86	1.21	1.06	0.75	+14.7	+ 61.3	+ 41.3
1.1	2.5	1.8	1.1	2.25	1.45	1.00	+10.0	+125.0	+ 45.0
0.8	2.2	1.5	0.88	1.85	1.37	1.00	-12.0	+ 85.0	+ 37.0
1.2	2.9	2.05	1.2	2.7	1.95	1.00	+20.0	+170.0	+ 95.0
1.03	2.5	1.78	1.06	2.25	1.66	1.00	+ 6.0	+125.0	+ 66.0
1.4	2.0	1.7	1.45	2.1	1.78	1.50	- 3.3	+ 40.0	+ 18.7
1.3	2.0	1.65	1.25	2.0	1.63	1.50	-16.7	+ 33.3	+ 10.7
2.0	2.8	2.4	2.0	2.8	2.4	1.50	+33.3	+ 86.7	+ 60.0
1.57	2.27	1.92	1.57	2.3	1.94	1.50	+ 4.7	+ 53.3	+ 29.3
2.4	3.3	2.85	2.4	3.3	2.85	2.00	+20.0	+ 65.0	+ 42.5
2.7	3.7	3.20	2.65	3.7	3.18	2.00	+32.5	+ 85.0	+ 59.0
2.8	3.5	3.15	2.8	3.5	3.15	2.00	+40.0	+ 75.0	+ 57.5
2.6	3.5	3.07	2.6	3.5	3.06	2.00	+30.0	+ 75.0	+ 53.0
Average Percent of Error for all tubes							+61.12		
							Average Max % E	Average Total St. Length	Average St. Length
							+ 11.0%	% E =	% E =
								+93.3%	+53.1%
ant the maximum point of concentricity on the tubes. Past this concentric but were slanted and irregular.									
it the maximum point of total stain length. This includes the stains not included in column 3.									
ant the average of the readings of columns 3 & 4.									

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Tube #	Concentration of Metranol in mgs/liter and temp. at time of test.	Observed mg/L	No of strokes of pumps	Equivalent $\frac{\text{mg}}{\text{L}} \times \frac{3}{4}$	TRUE mg/L
1	0.2175 @ 25°C	5.0	17	1.4706	0.2175
2	" "	3.0	10	1.5000	0.2175
3	" "	2.5	9	1.3888	0.2175
AVERAGE	0.2175 @ 25°C	3.5	12	1.4583	0.2175
4	0.290 @ 25°C	1.0	6	0.8333	0.290
5	" "	1.5	7	1.0714	0.290
6	" "	1.0	7	0.7143	0.290
AVERAGE	0.290 @ 25°C	1.17	6.67	0.8771	0.290
7	0.3625 @ 25°C	1.5	7	1.0714	0.3625
8	0.3625 @ 25°C	1.5	6	1.2500	0.3625
9	" "	1.5	6	1.2500	0.3625
AVERAGE	0.3625 @ 25°C	1.5	6.33	1.1848	0.3625
10	0.435 @ 25°C	1.5	5	1.5000	0.435
11	" "	1.0	5	1.0000	0.435
12	" "	1.0	6	0.8333	0.435
AVERAGE	0.435 @ 25°C	1.17	5.33	1.0976	0.435
13	1.305 @ 25°C	5.0	5	5.000	1.8
14	1.305 @ 25°C	3.0	4	3.750	1.8
AVERAGE	1.305 @ 25°C	4.0	4.5	4.4444	1.8
15	4.350 @ 25°C	13.0	5	13.000	6.0
16	" "	18.0	5	18.000	6.0
AVERAGE	4.350 @ 25°C	15.5	5	15.500	6.0
					Average

ALCOHOL DETECTOR TEST

Exp. Date of Tube
Batch No. 8305

Dec 1960

(6)		(7)							
TRUE		% ERROR							
mg/L		(d)-(6)							
		6							
0.2175		576.1							
0.2175		589.7							
0.2175		538.5							
0.2175		570.5							
0.290		187.3							
0.290		269.4							
0.290		146.3							
0.290		202.4							
0.3625		195.6							
0.3625		244.8							
0.3625		244.8							
0.3625		226.8							
0.435		244.8							
0.435		129.9							
0.435		91.6							
0.435		152.3							
1.8		177.8							
1.8		108.3							
1.8		146.9							
6.0		116.7							
6.0		200.0							
6.0		158.3							
Average %	Error for all tubes	= 242.9							

2

Date of test: 26 April 60
13 May 60

Tested by: Beecher; Dankman

KIT # 2 TRICHLOROETH

(1) TUBE NUMBER	(2) Test concentration in mg/liter, and temperature at time of test	(4) length of stain (cm)	(5) length of reaction layer (cm)	(6) RATIO	(7) Meas pp
1	0.25 mg/liter @ 21.6°C	1.45	5.2	0.28	4
2	" "	1.70	5.1	0.33	5
3	" "	1.60	5.5	0.29	4
AVERAGE	" "	1.58	5.27	0.30	4
4	0.50 mg/liter @ 23.5°C	1.80	5.6	0.32	5
5	" "	1.60	5.3	0.30	4
6	" "	2.50	5.6	0.45	10
AVERAGE	" "	1.97	5.5	0.36	6
7	1.00 mg/liter @ 24.2°C	1.70	5.2	0.33	5
8	" "	2.80	5.3	0.53	16
9	" "	3.20	5.4	0.59	20
AVERAGE	" "	2.59	5.3	0.49	13
10	1.50 mg/liter @ 25°C	3.95	5.7	0.69	29
11	" "	4.15	6.2	0.67	27
12	" "	4.20	6.5	0.65	25
AVERAGE	" "	4.10	6.1	0.67	27
13	2.00 mg/liter @ 25°C	4.60	6.4	0.72	34
14	" "	5.10	6.2	0.82	40
15	" "	4.50	5.8	0.78	40
AVERAGE	" "	4.73	6.1	0.78	38
** See remarks		**** Average percent of error for			
REMARKS:		The results from tubes # 4, 5 & 7 were not consistent with			
		This is due to the fact that when these tubes were tested			
		corrected for all the other tests, but the results obtained			
		enough to create an overall 12 % of error. Without the le			
		involved that the overall percent of error would be less t			
		Tubes #10 through # 15 were tested on 13 May 60, while al			

1

KIT # 2 TRICHLOROETHYLENE TUBE TEST

Expiration date of tubes: 17 Sept 60 (Tubes 1 - 10)
30 Oct 60 (Tubes 10 - 15)

(5) length of reaction layer (cm)	(6) RATIO	(3) Measured PPM	(7) TRUE PPM	(8) Percent of error (3)-(7)/(7)						
5.2	0.28	40	46.5	-14%						
5.1	0.33	50	46.5	+7.5%						
5.5	0.29	45	46.5	-3.2%						
5.27	0.30	45	46.5	-3.2%						
5.6	0.32	50	93.0	-46.2%						
5.3	0.30	45	93.0	-51.6%						
5.6	0.45	100	93.0	+7.5%						
5.5	0.36	65	93.0	-30.1%						
5.2	0.33	50	186.0	-73.1%						
5.3	0.53	160	186.0	-14.0%						
5.4	0.59	200	186.0	+7.5%						
5.3	0.49	137	186.0	-26.3%						
5.7	0.69	295	279.0	+5.7%						
6.2	0.67	270	279.0	-3.2%						
6.5	0.65	250	279.0	-10.4%						
6.1	0.67	272	279.0	-2.5%						
6.4	0.72	340	372.0	-8.6%						
6.2	0.82	400	372.0	+7.5%						
5.8	0.78	400	372.0	+7.5%						
6.1	0.78	380	372.0	+2.2%						
Average percent of error for all tubes used: (-)12.0%										
7 were not consistent with the results obtained from the other tubes. When these tubes were tested the hand pump used was leaking. This was s, but the results obtained with these three specific tubes were % of error. Without the leaking pump, it seems from the other data % of error would be less than 4.0%.										
tested on 13 May 60, while all the others were tested on 26 April 60										

2

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Date of test: 12 May 60
(1) (2)

Tested by: Dankman, Beecher
Observers: Hyatt, Beecher, Dankman
(3) (4) (5)

KIT #2 TOLUENE TUBE TEST #1
(6) (7) (8) (9)

TUBE NUMBER	Test concentration in mg/liter; and temperature at time of test.	PPM	OBSERVER NUMBER 1. length of stain (cm)	length of reaction layer (cm.)	RATIO (4)/(5)	PPM	OBSERVER NUMBER 2. length of stain (cm)	length of reaction layer (cm.)
1	0.25 mg/liter @ 24°C	65	1.95	6.50	0.30	65	2.00	6.50
2	" "	50	1.90	7.20	0.26	50	2.00	7.25
3	" "	50	1.80	6.65	0.27	50	1.75	6.65
AVERAGE	" "	55	1.88	6.68	0.28	55	1.92	6.80
4	0.75 mg/liter @ 26°C	220	4.00	6.90	0.58	250	4.20	6.80
5	" "	160	3.40	7.00	0.49	160	3.45	6.95
6	" "	160	3.40	6.95	0.49	150	3.35	6.95
AVERAGE	" "	180	3.60	6.95	0.52	187	3.67	6.90
7	1.00 mg/liter @ 28°C	265	4.30	7.00	0.61	255	4.25	7.10
8	" "	230	4.45	7.70	0.58	210	4.40	7.80
9	" "	260	4.10	6.70	0.61	240	3.95	6.75
AVERAGE	" "	252	4.28	7.13	0.60	235	4.20	7.22
10	1.50 mg/liter @ 28.5°C	345	3.95	6.00	0.66	305	3.85	6.00
11	" "	380	4.60	6.95	0.66	335	4.50	6.95
12	" "	400	4.45	6.60	0.67	375	4.35	6.60
AVERAGE	" "	375	4.33	6.52	0.66	338	4.23	6.52
13	2.00 mg/liter @ 24°C	600	5.20	6.85	0.76	600	5.20	6.90
14	" "	600	5.10	6.75	0.76	600	5.10	6.75
15	" "	600	5.30	7.00	0.76	610	5.35	7.05
AVERAGE	" "	600	5.20	6.87	0.76	606	5.22	6.90

REMARKS: On tubes # 9 and # 12, the front end of the stain was slanted for approximately one-eight.								
On tube # 8, the PPM readings were obtained by extrapolating the lines on the concentration chart.								
On tubes # 13, # 14, and # 15, the PPM were at best only estimates. We could only ascertain a small distance on the calibration chart represents a large change in concentration.								
***** The figures for the temperature correction factor were obtained by subtracting 5% of								

1

2 TOLUENE TUBE TEST #1
 (7) (8) (9) (10) (11)

PPM	OBSERVER length of stain (cm)	NUMBER 2. length of reaction layer (cm)	RATIO (8)/(9)	Average PPM (3)+(7)/2	Tempera- ture correction (PPM)	Corrected PPM (11)-(12)	True PPM	Percent of error (13)-(14)
65	2.00	6.50	0.31	65	2.34	62.66	66.50	-5.8%
50	2.00	7.25	0.28	50	1.80	48.20	66.50	-27.5%
50	1.75	6.65	0.26	50	1.80	48.20	66.50	-27.5%
55	1.92	6.80	0.28	55	1.98	53.02	66.50	-20.3%
250	4.20	6.80	0.62	235	12.69	222.31	199.50	+11.4%
160	3.45	6.95	0.50	160	8.64	151.36	199.50	-24.1%
150	3.35	6.95	0.48	155	8.37	146.63	199.50	-26.5%
187	3.67	6.90	0.53	183.5	9.91	173.59	199.50	-13.0%
255	4.25	7.10	0.60	260	18.72	241.28	266.00	-9.3%
210	4.40	7.80	0.56	220	15.84	204.16	266.00	-23.2%
240	3.95	6.75	0.59	250	18.00	232.00	266.00	-12.8%
235	4.20	7.22	0.58	243.5	17.53	225.97	266.00	-15.0%
305	3.85	6.00	0.64	325	24.86	300.14	399.00	-24.8%
335	4.50	6.95	0.65	357.5	27.35	330.15	399.00	-16.5%
375	4.35	6.60	0.66	387.5	29.64	357.89	399.00	-10.3%
38	4.23	6.52	0.65	356.5	27.27	329.23	399.00	-17.5%
600	5.20	6.90	0.75	600	21.60	578.40	532.00	+8.7%
600	5.10	6.75	0.76	600	21.60	578.40	532.00	+8.7%
610	5.35	7.05	0.76	605	21.78	583.22	532.00	+9.6%
606	5.22	6.90	0.76	603	21.71	581.29	532.00	+9.3%
**** Average percent of error for all								11.3%
for approximately one-eighth of an inch (PPM readings used were mid-point of slant readings the lines on the concentration chart. (Extending lines far enough to be read) imates. We could only ascertain that the readings were between 575 PPM and 675 PPM since a ge change in concentration.								
obtained by subtracting 5% of the average PPM (11) for each 10°F above 20°C.								

2

Date of test: 30 June 1960 (1) (2)		Tested by: Beecher & Dankman (3) (4) (5)		Observers: Beecher and Thorpe (6) (7) (8)			
TUBE NUMBER	Test concentration in mgs/liter; and tempera- ture at time of test.	Observed PPM	OBSERVER NUMBER 1 length of stain (cm)	length of reaction layer (cm)	RATIO (4) / (5)	Observed PPM	OBSERVER length of stain (cm)
1	0.25 mg/liter @ 21.1°C	50	1.85	7.6	0.24	50	1.85
2	" "	50	1.9	7.6	0.25	50	1.9
3	" "	65	2.4	7.75	0.31	65	2.4
AVERAGE	" "	55	2.05	7.65	0.27	55	2.05
4	0.75 mg/liter @ 23.4°C	150	3.4	7.6	0.45	145	3.4
5	" "	125	3.0	7.6	0.39	125	3.0
6	" "	125	2.7	6.9	0.39	125	2.7
AVERAGE	" "	133	3.0	7.4	0.41	132	3.0
7	1.00 mg/liter @ 24.0°C	155	3.4	7.4	0.46	150	3.4
8	" "	140	3.2	7.3	0.44	130	3.2
9	" "	135	3.8	7.2	0.42	145	3.1
AVERAGE	" "	143	3.2	7.3	0.44	142	3.2
10	1.50 mg/liter @ 25.0°C	270	3.9	7.1	0.55	275	3.9
11	" "	325	4.2	7.1	0.59	330	4.2
AVERAGE	" "	290	4.1	7.1	0.58	303	4.1
12	2.00 mg/liter @ 25.0°C	550	4.7	7.3	0.64	550	4.7
13	" "	540	5.2	7.7	0.68	540	5.2
AVERAGE	" "	545	5.0	7.5	0.67	545	5.0
REMARKS: On tubes # 3, 4, 5 and 7 the resultant stain was slanted for app. 1/4" of the slanted portion of the stain.							
On tubes # 9, 10, 11, 12, and 13. The resultant stain was slanted for a mid-point of the slanted portion of the stain.							
* The temperature correction factor (12) was obtained by subtracting from 10°F above 20°C.							

1

Observers: Beecher and Thorpe
 (6) (7) (8) KIT #2 TOLUENE DETECTOR TUBE (TEST #2) Expiration Date of Tubes: 1 Aug 1960
 (9) (10) (11) (12) (13) (14) (15)
 BATCH No. 0118050

RATIO (4) / (5)	Observed PPM	OBSERVER length of stain (cm)	NUMBER 2 length of reaction layer (cm)	RATIO (8) / (9)	AVERAGE PPM (3)+(7)/(2)	Temperature Correction (PPM) *				
0.24	50	1.85	7.6	0.24	50	0.50	49.50	66.5	-25.6	
0.25	50	1.9	7.6	0.25	50	0.50	49.50	66.5	-25.6	
0.31	65	2.4	7.75	0.31	65	0.65	64.35	66.5	-3.2	
0.27	55	2.05	7.65	0.27	55	0.55	54.45	66.5	-10.1	
0.45	145	3.4	7.65	0.44	148	5.18	142.82	199.5	-28.4	
0.39	125	3.0	7.6	0.39	125	4.38	120.62	199.5	-29.5	
0.39	125	2.7	6.9	0.39	125	4.38	120.62	199.5	-32.5	
0.41	132	3.0	7.4	0.41	133	4.66	128.34	199.5	-35.7	
0.46	150	3.4	7.45	0.46	153	5.51	147.49	266	-43.0	
0.44	130	3.2	7.45	0.43	135	4.86	130.14	266	-51.1	
0.42	145	3.1	7.2	0.43	140	5.04	134.96	266	-49.3	
0.44	142	3.2	7.4	0.43	143	5.15	137.85	266	-48.2	
0.55	275	3.9	7.1	0.55	273	12.29	260.71	399	-32.4	
0.59	330	4.2	7.1	0.59	328	14.76	313.24	399	-21.5	
0.58	303	4.1	7.1	0.58	301	13.55	287.45	399	-28.0	
0.64	550	4.7	7.3	0.64	550	24.75	525.25	532	-1.3	
0.68	540	5.2	7.7	0.68	540	24.30	515.70	532	-3.1	
0.67	545	5.0	7.5	0.67	545	24.53	520.47	532	-2.2	
Average Percent of Error for all tubes-----									-26.4%	
Stain was slanted for app. 1/4". Readings were taken at the mid-point.										
Residual stain was slanted for app. 1/8". Readings were taken at the										
of the stain.										
was obtained by subtracting from the average PPM(11) 5%, for each										

2

Date of Test: 28 July 60 (1) (2)		Observers: Beecher and Dankman (3) (4)		KIT #2 METHANOL DETECTOR TUB (5)	
Tube #	Concentration in mgs/L and temp. @ time of test	OBSERVED PPM	TEMPERATURE CORRECTION	CORRECTED PPM (3) - (4)	
1	0.073 @ 24°C	225	-24.3	200.7	
2	" "	225	-24.3	200.7	
AVERAGE	" "	225	-24.3	200.7	
3	0.146 @ 24°C	225	-24.3	200.7	
4	" "	280	-30.2	249.8	
AVERAGE	" "	252.5	-27.3	225.2	
5	0.2175 @ 25°C	225	-30.4	194.6	
6	" "	225	-30.4	194.6	
AVERAGE	" "	225	-30.4	194.6	
7	0.290 @ 25°C	280	-37.8	242.2	
8	" "	225	-30.4	194.6	
AVERAGE	" "	252.5	-34.1	218.4	
9	0.3625 @ 25°C	300	-40.5	259.5	
10	" "	280	-37.8	242.2	
AVERAGE	" "	290	-39.2	250.8	
11	0.435 @ 25°C	280	-37.8	259.5	
12	" "	280	-37.8	259.5	
AVERAGE	" "	280	-37.8	259.5	
13	1.305 @ 25°C	500	-67.5	432.5	
14	" "	500	-67.5	432.5	
AVERAGE	" "	500	-67.5	432.5	
15	4.350 @ 25°C	600	-81.0	519.0	
16	" "	700	-94.5	605.5	
AVERAGE	" "	650	-87.8	562.2	
					Average %

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TABLE NO. 6

ET #2

METHANOL DETECTOR TUBE TEST

Exp. Date of Tubes: 29 July 62

Cat. No.: 119

(5)	(6)	(7)						
CORRECTED PPM (3) - (4)	TRUE PPM	% ERROR (5)-(6) 6						
200.7	55.7	260.3						
200.7	55.7	260.3						
200.7	55.7	260.3						
200.7	111.4	80.2						
249.8	111.4	124.2						
225.2	111.4	102.2						
194.6	167.1	16.5						
194.6	167.1	16.5						
194.6	167.1	16.5						
242.2	221.3	9.4						
194.6	221.3	(-) 12.1						
218.4	221.3	(-) 1.3						
259.5	276.6	(-) 6.2						
242.2	276.6	(-) 8.8						
250.8	276.6	(-) 7.5						
259.5	331.9	(-) 21.8						
259.5	331.9	(-) 21.8						
259.5	331.9	(-) 21.8						
432.5	995.7	(-) 56.6						
432.5	995.7	(-) 56.6						
432.5	995.7	(-) 56.6						
519.0	322.0	(-) 83.9						
605.5	322.0	(-) 81.2						
562.2	322.0	(-) 82.5						
Average % of Error for all tubes *		+26.2%						

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EXPLANATORY NOTE

As few changes as appeared to be necessary have been made by the authors and/or the editor, in the papers presented at this, the first Annual USAF Sanitary and Industrial Hygiene Engineering Symposium.

Unfortunately, because of limitations on space and reproduction facilities, it was necessary in some cases to delete questions from the floor as well as illustrative material.